National Aeronautics and
Space Administration

Budget Estimates

Fiscal Year 2000

Agency Summary

International Space Station

Launch Vehicles and Payload Operations

Science, Aeronautics, and Technology

Mission Support

Inspector General

TABLE OF CONTENTS

FY 2000 CONGRESSIONAL BUDGET

TABLE OF CONTENTS

FY 2000 CONGRESSIONAL BUDGET

USEFUL NASA WEBSITES

FY 2000 CONGRESSIONAL BUDGET

NASA	http://www.nasa.gov/
NASA Headquarters	http://www.hq.nasa.gov/
NASA Strategic Plan	http://www.hq.nasa.gov/office/nsp/
NASA Strategic Management Handbook	http://www.hq.nasa.gov/office/codez/strahand/frontpg.htm
Chief Financial Officer	http://ifmp.nasa.gov/codeb/
Budget Request	http://ifmp.nasa.gov/codeb/budget/
Public Affairs	http://www.nasa.gov/newsinfo/index.html
Legislative Affairs	http://www.hq.nasa.gov/office/legaff/
Human Resources and Education	http://www.hq.nasa.gov/office/codef/
Procurement	http://www.hq.nasa.gov/office/procurement/
Safety and Mission Assurance	http://www.hq.nasa.gov/office/codeq/
Small and Disadvantaged Business Utilization	http://www.hq.nasa.gov/office/codek/
External Relations	http://www.hq.nasa.gov/office/codei/
Inspector General	http://www.hq.nasa.gov/office/oig/hq/
Aeronautics Enterprise	http://www.aero.hq.nasa.gov/
Earth Science Enterprise	http://www.hq.nasa.gov/office/mtpe/
Human Exploration and Development of Space Enterprise	http://www.osf.hq.nasa.gov/heds/
Office of Space Flight	http://www.osf.hq.nasa.gov/
Office of Microgravity Life Sciences and Applications	http://www.hq.nasa.gov/office/olmsa/
Space Science Enterprise	http://www.hq.nasa.gov/office/oss/
Ames Research Center	http://www.arc.nasa.gov/
Dryden Flight Research Center	http://www.dfrc.nasa.gov/dryden.html
Goddard Space Flight Center	http://www.gsfc.nasa.gov/
Wallops Flight Facility	http://www.wff.nasa.gov/
Goddard Institute for Space Studies	http://www.giss.nasa.gov/
Jet Propulsion Laboratory	http://www.jpl.nasa.gov/
Johnson Space Center	http://www.jsc.nasa.gov/
White Sands Test Facility	http://www.wstf.nasa.gov/
Kennedy Space Center	http://www.ksc.nasa.gov/ksc.html
Langley Research Center	http://www.larc.nasa.gov/larc.cgi
Lewis Research Center	http://www.lerc.nasa.gov/LeRC_homepage.html
Marshall Space Flight Center	http://www.msfc.nasa.gov/
Stennis Space Center	http://www.ssc.nasa.gov/
Independent Validation and Verification Facility	http://www.ivv.nasa.gov/
NASA Advisory Council	http://www.hq.nasa.gov/office/codez/nac/nac.htm

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 BUDGET ESTIMATES

NASA'S VISION FOR THE FUTURE

NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

NASA's unique mission of exploration, discovery, and innovation has preserved the United States' role as both a leader in world aviation and as the preeminent spacefaring nation. It is NASA's mission to:

- Explore, use and enable the development of space for human enterprise;
- Advance scientific knowledge and understanding of the Earth, the Solar System, and the Universe and use the environment of space for research;
- Research, develop, verify and transfer advanced aeronautics, space and related technologies.

The outcomes of NASA's activities contribute significantly to the achievement of America's goals in four key areas:

- Economic growth and security - NASA conducts aeronautics and space research and develops technology in partnership with industry, academia, and other federal agencies to keep America capable and competitive.
- Preserving the Environment - NASA studies the Earth as a planet and as a system to understand global climate change, enabling the world to address environmental issues.
- Educational Excellence - NASA involves the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds.
- Peaceful Exploration and Discovery - NASA explores the Universe to enrich human life by stimulating intellectual curiosity, opening new worlds of opportunity, and uniting nations of the world in this quest.

To fulfill NASA's mission of exploration, discovery and innovation, NASA sets the following overarching goals to take its science and aeronautics program proudly into the 21st century:

NASA will be at the forefront of exploration and science. We will develop and transfer cutting-edge technologies in aeronautics and space. NASA will establish a permanent human presence in space.

As NASA pursues its mission, NASA will enrich the Nation's society and economy. NASA will contribute to a better life for this and future generations.

In the coming decades, it is our goal to undertake bold and noble challenges -- exciting future programs, which stir the imagination and fall within the grasp of the United States and its international partners' technical and financial grasp.

The President's national space policy, released in September 1996, underscores NASA's role as the lead Federal Agency for civil space R&D. It features NASA's strengthening of its focus on cutting edge R&D and deemphasis on operational activities. The policy highlights priorities in human space flight (the International Space Station), science (Earth observation, continuous robotic presence on Mars surface, celestial sample returns and search for other Earth-like planets), and space technology (reusable launch vehicles and smaller, cheaper space missions). It also underscores NASA's leveraging of industry through purchases of launch services, spacecraft, data products, communication services, and new technology; and continued close coordination with the Department of Defense (DoD), the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), Department of Transportation, etc.

STRATEGY FOR ACHIEVING OUR GOALS

The NASA budget request for FY 2000 continues the President's commitment to invest in the future. This budget request recognizes the enormous potential for investments in the civil space and aeronautics program to benefit this country. The President's Space Policy, issued in September 1996, outlined a strong and stable program in space that will ensure America's role as the world's space leader. The Space Policy reaffirmed the United States' commitment to the International Space Station, to the next generation of launch vehicle programs, to an aggressive space science program, and to the continuing commitment to a long-term program of environmental monitoring from space. The President's strategy for investing in science and technology, encompassing goals which emphasize world leadership in science, mathematics and engineering, economic growth, improved environmental quality, and harnessing information technology continues as the framework for development of federal science and technology policy. The President's budget request for NASA for FY 2000 fully supports these goals.

The NASA budget request for FY 2000 is reflected in five appropriations:

International Space Station - providing funding for International Space Station, including development of research facilities;

Launch Vehicles and Payload Operations – providing funding for the operation, maintenance and upgrades to the Space Shuttle fleet, as well as integration and support for Shuttle payloads and Expendable Launch Vehicles (ELVs);

Science, Aeronautics and Technology - providing funding for NASA's research and development activities, including all science activities, global monitoring, aeronautics, technology investments, education programs, mission communication services and direct program support;

Mission Support - providing funding for NASA's civil service workforce, space communication services, safety and quality assurance activities, and facilities construction activities to preserve NASA's core infrastructure;

Inspector General - providing funding for the workforce and support required to perform audits and evaluations of NASA's programs and operations.

Each Enterprise, similar to the strategic business units employed by the private sector, has a unique set of strategic goals, objectives, and concerns, and a unique set of primary external customers. NASA also provides capabilities that are required for each Enterprise to achieve its goals and meet the needs of their customers. These agency-level activities serve multiple Enterprises and the strategies of these functions are driven primarily by the strategic plans of the Enterprises. The fundamental values of excellence, responsibility, teamwork, trust, and honor form the bedrock of all of NASA's activities.

NASA's Strategic Plan transcends its organizational structure. Each of the Strategic Enterprises seeks to respond to a unique customer community. Each of the Enterprises has its own set of technology needs which are closely linked to performing future planned missions while reducing the cost and technical risk. At the same time, there is considerable synergy between the Enterprise activities, which strengthens each Enterprise. The Strategic Enterprises comprise an integrated national effort. Synergism of broad purposes, technology requirements, workforce skills, facilities, and many other dimensions was the basis for amalgamating these activities within NASA in the National Aeronautics and Space Act in 1958, and the benefits remain strong today.

A broad description of the focus of each Strategic Enterprise follows:

Space Science - The activities of the Space Science Enterprise seek answers to fundamental questions, such as understanding the origin and evolution of the universe and our solar system, if there are planets around other stars, whether the Earth is unique, and if life exists elsewhere. The quest for this information, and the answers themselves, maintains scientific leadership, excites and inspires our society, strengthens education and scientific literacy, develops and transfers technologies to promote U.S. competitiveness, fosters international cooperation to enhance programs and share their benefits, and sets the stage for future space ventures.

Earth Science - The activities that comprise this Enterprise are dedicated to understanding the total Earth system and the effects of humans on the global environment. This pioneering program of studying global climate change is developing many of the capabilities that will be needed indefinitely, for long-term environment and climate monitoring and prediction. Governments around the world need information based on the strongest possible scientific understanding. The unique vantage point of space provides information about the Earth's land, atmosphere, ice, oceans, and biota as a global system, which is available in no other way. In concert with the global research community, the Earth Science Enterprise is developing the understanding needed to support the complex environmental policy decisions that lie ahead.

Human Exploration and the Development of Space - The Human Exploration and Development of Space Enterprise seek to bring the frontiers of space fully within the sphere of human activities. HEDS conducts research and development to sustain a permanent human presence in space in low-Earth orbit. HEDS will use the environment of space for research on biological, chemical and physical processes and facilitates the development of space for commercial enterprise. In pursuit of these goals, HEDS delivers knowledge and technologies that help to improve medical care and industrial processes on Earth while strengthening education and scientific literacy.

Aero-Space Technology - - The Aero-Space Technology Enterprise features the Aeronautics and Space Transportation programs.

NASA, and its predecessor, the National Advisory Committee for Aeronautics, have worked closely with U.S. industry, universities, and other Federal agencies to give the United States a preeminent position in Aeronautics. The Aeronautics program will pioneer the identification, development, verification, transfer, application and commercialization of high-payoff aeronautics technologies. Activities pursued as part of this Enterprise emphasize customer involvement, encompassing U.S. industry, the Department of Defense, and the Federal Aviation Administration. NASA is playing a leadership role as part of a Government-industry partnership to develop breakthrough technology that will help the aviation community cut the fatal accident rate five-fold within ten years and ten-fold within twenty years. This new initiative, combined with the NASA investment in Air Traffic Management technology will enhance aviation safety and capacity called for by the White House Commission on Aviation Safety and Security chaired by Vice President Gore. The Space Transportation Technology program will develop new technologies aimed at access to space. The targeted technologies will reduce launch costs dramatically over the next decade, as well as increase the safety and reliability of current and future generation launch vehicles. Additionally, new plateaus of performance for in-space propulsion will be established, while reducing cost and weight.

NASA's ability to inspire and expand the horizons of present and future generations rests on the success of these efforts to maintain this nation's leadership in space within the reality of the fiscal constraints facing the federal budget. In order to ensure the stability to manage and execute programs within budget and schedule, NASA is seeking multi-year appropriations for the International Space Station.

PLANS AND ACCOMPLISHMENTS

The NASA programs achieved many impressive successes in 1998; for example, the in-orbit assembly of the first two first elements of the International Space Station, the launch of new missions to Mars, additional scientific discoveries by the Hubble Space Telescope, Space Shuttle science research missions, the last of which included the return to orbit of Senator John Glenn, and many others. The funding provided in the FY 1999 appropriation and in the FY 2000 budget request will enable NASA to capitalize on these successes, whether it be producing outstanding science and technology, assembling and operating the International Space Station, or development of the next-generation Reusable Launch Vehicle. All of these are being done with an overriding emphasis on safety.

The emphasis on cheaper, more capable science missions is continued in the FY 2000 budget request. These programs experiment with new innovative management and procurement practices, promote smaller affordable missions and enforce strict adherence to performance criteria and cost caps.

NASA has been at the forefront of the Administration's efforts to reshape the federal government, to make it smaller, cut costs, and be more responsive to the ultimate customer, the taxpayer. NASA's civil service workforce was reduced an additional 440 full time equivalents (FTEs) over the FY 1998 baseline of 19,364. Total civil service employment for NASA at the end of FY 1998 was 18,924 FTEs. This progress, combined with the FY 1997 reduction of 618 FTEs, has reduced the NASA workforce by over 1,000 FTEs in the last two years, with an additional reduction of approximately 350 FTEs planned by the end of FY 1999.

NASA continues to be a leader in responding to the challenge of reducing the federal deficit and the goals of the National Performance Review. Over the past several years, NASA has undergone a thorough scrutiny of its mission, organization and activities. A strengthened program management system has been implemented and the Program Management Council regularly reviews the technical, schedule and financial status of NASA's major activities. A disciplined process has been established for the early identification of problems, and guidelines for addressing a solution. This process has resulted in senior management attention focused on program performance. The Strategic Management process put into place provides a continuous process for NASA to make critical decisions about its long-term goals, near-term activities, and institutional capabilities that are in alignment with customer requirements. A fundamental goal of NASA's Strategic Management process is to ensure that the Agency provides its customers with excellent products and services in the most cost-effective and timely manner.

INTERNATIONAL SPACE STATION

This appropriation encompasses the development and operation of the International Space Station (ISS), including the scientific research facilities. The ISS is the culmination of the redesign work begun in FY 1993 to reduce program costs while still providing significant research capabilities. Space Station partners include NASA, the Russian Space Agency (RSA), European Space Agency (ESA), the Canadian Space Agency (CSA), and the National Space Development Agency of Japan (NASDA). The partnerships significantly enhance the capabilities of the International Space Station, and ensure compatible interfacing elements. A single contractor, Boeing North American, which has total development and integration responsibilities, leads the program. The NASA program office at the Johnson Space Center has primary management responsibility for the program, including responsibility for bringing the systems and elements into integrated launch packages.

The Administration continues to be strongly committed to development of the International Space Station, and the preservation of the partnerships between the United States, Russia, Europe, Japan and Canada. Station assembly began in late-1998 and will continue through 2004. The proposed budget provides multi-year funding for development and operation of the Station. Sufficient additional funding is being requested for the International Space Station to maintain the program on schedule and minimize the total cost, while providing contingency activities to mitigate the risk of potential Russian shortfalls.

During the past year, the Space Station program has focused on the continued qualification testing, manufacturing, and assembly and integration of flight hardware. Phase 1 of the program was completed with the ninth Shuttle-Mir flight. Phase 2 began with the successful launch of the Zarya module in November 1998 and the subsequent launch of Unity, the first pressurized node, in December. Unity, including two pressurized mating adapters, was successfully attached to Zarya during assembly flight 2A. In 1998, the laboratory module was completed and readied for delivery to the Kennedy Space Center in the first quarter of FY 1999. Multi-Element Integrated Test (MEIT) activities were initiated and will continue in FY 1999 for flights 3A, 4A, 5A (Lab), and 6A. Activities also continued to support crew training, payload processing, and hardware element processing requirements. The International Space Station partners continued development of flight hardware.

During FY 1999, the major program focus will be the support of logistics launches (2A.1 and 2A.2) in mid- to late-FY 1999, and support for the launch of the Russian Service Module in late FY 1999. MEIT activities for Z1 truss (3A) and the photovotaic arrays on P6 (4A) will be completed by the end of FY 1999, and MEIT for the Lab (5A), Multi-Purpose Logistics Module (MPLM) and the Space Station Remote Manipulator System (SSRMS) will be performed. The airlock, to be flown on 7A in late FY 2000, will complete assembly, checkout and qualification testing for those elements. Preparation for the two utilization flights in FY 2001 (UF-1 and UF-2) is planned, including the start of assembly of EXPRESS racks that will carry experiments in the Lab. Development of orbiter Reaction Control System (RCS) interconnects will continue in FY 1999, and plans are to begin development of a U.S. built propulsion capability to mitigate the risk of potential shortfalls of the Russian system, and to provide a more robust reboost and control function for the ISS.

Seven U.S. assembly and logistics flights are planned for FY 2000, completing Phase 2 of the program with the launch of the airlock on flight 7A in the latter part of the fiscal year. The start of the development of the crew return vehicle is planned in this year, with a target of providing the first vehicle for deployment in FY 2004. Preparations for research utilization, and the buildup of Phase 3 assembly elements will be a high priority.

Funding for all elements of the Space Station program is included in the appropriation request for the International Space Station. Program elements included in the International Space Station budget are: Vehicle (development of flight hardware), Operations Capability, Research (development and utilization of research facilities), Russian Program Assurance, and the Crew Return Vehicle. Program reserves provide the capability to address technical and contract performance issues that will occur during this peak period of Space Station assembly and integration, test, and deployment.

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

This appropriation provides for the safe and efficient operation of the Space Shuttle, as well as support to Shuttle and ELV payloads. The highest priority of the Shuttle program remains the safe launch, operation and return of the orbiter and crew. Funding is included to continue modifications that will significantly improve the Space Shuttle's overall safety, including modifications to the Main Engine and the Orbiter, as well as continuation of the program of upgrades to increase reliability and maintainability. Transition to a consolidation of Space Shuttle operations contracts into a single prime contractual arrangement was started in October 1996. Transition activities will continue over the next 2 years and be completed in FY 2001. It is expected that this consolidation will achieve the challenge of finding additional cost savings in the outyears. These savings have been incorporated into NASA's budget planning.

In FY 1998, the Space Shuttle launched four flights successfully. Flights included the last Spacelab mission (Neurolab), two re-supply flights to the Russian Space Station Mir, and the United States Microgravity Payload (USMP) with a Spartan payload. The Alpha Magnetic Spectrometer (AMS) investigation was also conducted on the second Mir mission which safely and successfully concluded the formal Phase One Shuttle-Mir program.

Six flights are manifested for FY 1999. The first mission included a Spartan payload, the Hubble Orbital Systems Test (HOST) platform, and a series of experiments by the National Institute on Aging. The crew of astronauts for this last mission included Senator John Glenn. The second mission this year was the extraordinarily successful launch, deployment and mating of Unity to the Zarya module. The Space Shuttle will support the International Space Station with three flights this year, including the initial assembly flight. The Shuttle will also fly the Shuttle Radar Topography Mission (SRTM), a joint DOD/NASA payload to digitally map 80% of the earth's surface. Finally, the Space Shuttle plans to deploy the last of the "Great Observatories" when it launches the Advanced X-Ray Astrophysics Facility (AXAF).

Eight flights are planned to fly during FY 2000, including seven International Space Station assembly flights and the third Hubble Space Telescope servicing mission.

The Payload Utilization and Operations budget supports a variety of goals, which include the processing and flight of Space Shuttle payloads. NASA payloads launched from Expendable Launch Vehicles (ELVs), ensuring the maximum return on the research investment, reducing operations costs, continuing implementation of flight and ground systems improvements, and supporting strategic investments in advanced technology needed to meet future requirements.

Space Science

NASA's Space Science activities seek to answer fundamental questions concerning the galaxy and the universe; the connection between the Sun, Earth and heliosphere; the origin and evolution of planetary systems; and, the origin and distribution of life in the universe. In 1998, the Space Science program produced many notable scientific accomplishments. Measurement of light from distant exploding stars led two research teams to conclude that the universe will expand forever at a constantly expanding rate. This discovery was characterized by the editors of Science magazine, the journal of the American Association for the Advancement of Science, as the top scientific advance of 1998. The Rossi X-ray Timing Explorer (RXTE) discovered a new type of star, know as a "magnetar", which generates extremely powerful magnetic fields. The Hubble Space Telescope (HST) continued to produce many discoveries, including a possible direct image of an extra-solar planet, and, working with RXTE and the Beppo-Sax mission, detected the largest explosion since the Big Bang. The Keck II telescope imaged the formation of a new solar system. Within our own solar system, the Mars Global Surveyor mission photographed portions of Mars with unprecedented clarity, revealing ancient riverbeds and numerous geological structures. The Lunar Prospector spacecraft detected the presence of water ice on the moon. This discovery has important implications for future mission concepts, including potential lunar colonies as well as human space flight missions beyond the Earth-Moon system. The Solar and Hemispheric Observatory produced spectacular images of comets plunging into the Sun, and also detected solar quakes. Also in the field of solar science, the Transition Region and Coronal Explorer produced the sharpest images to date of magnetic reconnections on the Sun. In late 1998, and early FY 1999, the New Millennium Deep Space-1 mission, the Submillimeter Wave Astronomy Satellite, and the Mars Climate Orbiter were launched successfully. These launches both capped off a highly successful year and initiated a period in which nine Space Science missions will be launched over a seven-month period. Other missions to be launched in this period include the Mars Polar Orbiter, the Stardust mission, the Wide Field Infrared Explorer, the Far Ultraviolet Spectroscopy Explorer, and the Advanced X-Ray Astrophysics Facility.

To capitalize on these successes during the past year, the NASA budget request for FY 2000 provides increased funding for Space Science. Space Science continues to focus on the Origins program and fundamental questions regarding the creation of the universe and planetary systems and the possibility of life beyond Earth. In addition to planning for the deployment of powerful telescopes to detect Earth-like planets elsewhere in our galaxy, planning continues for a Europa mission to launch in 2003 to directly observe potential subsurface oceans on Europa. The Mars Surveyor Program is augmented to enhance the Mars 2001 lander, as well as to enhance future Mars missions through development of a Mars Telecommunications Network and Mars micro-missions. NASA will also initiate a series of Solar-Terrestrial Probes to track solar phenomena and their impact on the Earth.

The Advanced X-ray Astrophysics Facility (AXAF) will be launched in April 1999. Development activities continue on the Relativity (Gravity Probe-B) mission, which is scheduled for launch in 2000. The Space Infrared Telescope Facility (SIRTF) initiated development in April 1998, with launch planned for December 2001. Development activities on the Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) mission continue in 1999, with launch planned in 2000. Development activities on the Stratospheric Observatory for Infrared Astronomy (SOFIA) continue to receive support. The upgraded Hubble Space Telescope

(HST) is providing new insights into our universe, Funding for HST continues to support operations, as well as preparation for the third servicing mission in 2000.

In Explorer missions, development activities continue in the Far Ultraviolet Spectroscopy Explorer (FUSE), scheduled for launch in 1999. Development is also underway for the Microwave Anisotropy Probe (MAP) and Imager for Magnetosphere-to-Aurora Global Exploration (IMAGE) Medium-Class Explorer (MIDEX) missions. MAP will be launched in November 2000, IMAGE in January 2000. Three Small (SMEX) missions started development in FY 1998: the High Energy Spectroscopic Imager (HESSI) is to launch in 2000; the Galaxy Evolution Explorer (GALEX) will launch in 2001; the Two Wide-Angle Neutral Atom Spectrometers (TWINS) has been selected as mission of opportunity, to be launched in 2002 and 2004. These missions emphasize reduced mission costs and accelerated launch schedules.

The Mars Global Surveyor entered Mars orbit in September 1997, the Mars Climate Orbiter was launched in December 1998 and the Mars Polar Lander was launched in January 1999. Funds are requested for the development of future Mars missions to be launched in 2001 and beyond. The third Discovery-class mission, Lunar Prospector, launched in 1998, and has completed its primary mission. The fourth Discovery mission, Stardust, is on schedule for launch in February 1999. Two Discovery missions selected in 1997are proceeding on schedule: the Comet Nucleus Tour (CONTOUR) will begin development in FY 2000 and will be launched in 2002; the Genesis solar wind sample return mission has begun development and will be launched in 2001. The New Millennium program is underway to provide flight demonstrations of critical new technologies which will greatly reduce the mass and cost of future science instruments and spacecraft subsystems, while maintaining or improving mission capabilities. The Deep Space-1 mission was launched in October 1998 and has validated its technologies. The Deep Space-2 mission, was launched along with the Mars Polar Lander on January 3,1999, and will arrive at Mars in December 1999.

The Space Science program is responsible for Agency-wide core technology development. Space Science is also undertaking and aggressive technology development effort to enable new missions to the outer planets, and to search for Earth-like planets around nearby stars. New technologies are also being pursued to enhance our capability to explore Mars and other solar system bodies robotically, and perhaps to confirm the past or current presence of life elsewhere in the solar system.

Life and Microgravity Sciences and Applications

NASA's Office of Life and Microgravity Sciences and Applications (OLMSA) program advances scientific knowledge to enable the development of space for human enterprise, and to transfer the knowledge and technologies to improve the quality of life for people on Earth. OLMSA implements its projects through ground-based research, research on unmanned free-flying vehicles, Space Shuttle Missions, successfully completed research using the Russian Mir Space Station, and, in the future, on the International Space station (ISS).

In FY 1998 the United States Microgravity Payload (USMP) mission series culminated with the flight of the USMP-4 mission and the Neurolab mission, a Spacelab mission conducted cooperatively with the National Institutes of Health (NIH) dedicated to life sciences research. During the USMP-4 mission researchers used remote commands (telescience) to conduct experiments in fundamental physics and materials science using experimental apparatus in the payload bay and combustion science research using a glovebox inside the Space Shuttle. The Neurolab mission focused on the most complex and least understood function of the human body – the physiology of the nervous system. During the Neurolab mission a series of integrated biological/medical experiments were performed. These experiments explored how the brain and nervous system interprets, responds, and adapts when challenged by a novel environment. NASA together Science Foundation will apply the information derived from these experiments to the health and safety of astronauts and to medical conditions here on Earth. FY 1998 saw the completion of NASA's highly successful missions to the Russian Mir Space Station. Research on FY 1998 Missions to Mir included disciplines such as biotechnology, biomedicine, and fundamental biology as well as experiments in combustion and materials sciences. Mir served as a testbed for research procedures for the ISS. In FY 1999, the program has flown one science mission (STS-95) on a Spacelab carrier with ISS precursor science experiments and is preparing for research on STS-107 scheduled for launch in late CY 2000. STS 95 included commercially sponsored research as well as research on the effects of aging conducted with the National Institute on Aging. These pathfinder missions provide a transition between Russian Mir Space Station and Spacelab and the onset of significant research capability on-board the ISS. FY 1999 has also seen the beginning of ISS assembly. In FY 2000, a new era in research will begin with the launch of the U.S. laboratory module for the ISS. The U.S. Laboratory module will allow initial Life and Microgravity hardware and experiments to be established aboard the ISS. As assembly of the ISS continues to advance, ISS Crew Health Care System components will be utilized to provide on-orbit medical, environmental and countermeasure capabilities for all ISS crew members. At the end of CY 2000, the program will fly STS-107, which is a dedicated Space Shuttle research mission that will extend previous research results and prepare for research operations on the ISS.

Earth Science

The programs in NASA's Earth Science Enterprise (ESE) improve our understanding of the total Earth system and the effects of natural and human-induced changes on the global environment. Earth Science is pioneering the new interdisciplinary field of research called Earth system science, born of the recognition that the Earth's land surface, oceans, atmosphere, ice sheets and *biota* are both dynamic and highly interactive. It is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, Earth Science is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. Earth Science has established three broad goals: 1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and *in situ* platforms; 2) disseminate information about the Earth system; and 3) enable productive use of Earth Science program science and technology in the public and private sectors.

The Earth Observing System (EOS), the centerpiece of Earth Science, is a program of multiple spacecraft, supporting technology and interdisciplinary science investigations to provide a long-term data set of key parameters needed to understand global climate change.

In 1998, the Earth Science program continued to make great progress analyzing data from significant scientific events detected from orbiting spacecraft and scientific campaigns. Multiple spacecraft and instruments have played an important role in predicting the El Niño event and will continue to track a possible La Niña. Images derived from the TOPEX-Poseidon satellite allowed the public to watch the progression of El Niño across the Pacific Ocean. Radarsat brought the first detailed radar map of Antarctica. A cooperative mission with Japan, the Tropical Rainfall Measuring Mission (TRMM) was launched and has proven to be valuable for both scientific research and development of new weather forecasting capabilities.

Planned 1999 Earth Science launches include the EOS AM-1, Landsat 7, Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) and the Hyperspectral EO-1 mission. In 2000, the Earth Science Systematic data set will be enhanced by launches of EOS PM, SeaWinds on ADEOS II, and the French Jason-1 Ocean Altimetry mission in 2000. In early 2001, the Triana mission is an Earth observation spacecraft to be located at the Sun-Earth L1 point providing a near-term real time, continuous high definition color view of the full sun-lit disc of the Earth. A selection was made in November 1999 for the Scripps Institution of Oceanography to build and conduct the Triana mission scheduled to launch.

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy Lidar (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. NASA has chosen for development one primary and two alternate small spacecraft missions. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – Climatologie Etendue des Nuages et des Aerosols (PICASSO-CENA) mission, led by NASA's Langley Research Center will be the next ESSP mission scheduled for launch in 2003.

Data from Earth Science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well beyond the Earth Science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government--anyone who wants the information.

The Earth Science program is essential to the discovery of new concepts and to the design of future missions. The research is coordinated through the U.S. Global Change Research Program (USGCRP), the Committee on the Environmental and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academy of Sciences.

Aero-Space Technology

The Aeronautics program provides a broad foundation of advanced technology to strengthen the United States' leadership in aviation, an industry that plays a vital role in the economic strength, transportation infrastructure and national defense of the United States. The NASA Aeronautics program provides the nation with leadership in high payoff critical technologies which are transferred to industry, the Department of Defense, and the Federal Aviation Administration for application to safe, superior and environmentally compatible U.S. civil and military aircraft, and for a safe and efficient National Aviation System. NASA's unique research capabilities contribute to the strengthening of America's aviation industry in many ways, and the FY 1999 program continues important investments required to pursue the high leverage technologies required to support both subsonic and supersonic aircraft safety and performance as well as the economic viability of subsonic aircraft.

Research activities conducted within the Research and Technology Base provide the vital foundation of expertise and facilities that meet a wide range of aeronautical technology challenges for the nation. The program provides a high technology, diverse-discipline environment that enables the development of new, even revolutionary, aerospace concepts and methodologies for applications in industry. Work within the R&T Base lays the foundation for future new focused technology programs to address specific, high value national needs and opportunities the long-term goals of the Aero-Space Technology Enterprise. This work constitutes a national resource of expertise and facilities that responds quickly to critical issues in safety, security, and the environment. These same technological resources contribute to the overall U.S. defense and non-defense product design and development capabilities.

NASA has initiated an Aviation Safety Program to develop and demonstrate the technologies and strategies necessary to reduce the aviation accident rate by a factor of five by 2007 and by a factor of ten by 2107. Research and technology developments will build upon the efforts of the current Research and Technology Base Programs to address accidents involving hazardous weather and controlled flight into terrain, human error caused accident and incidents, and mechanical or software malfunctions. The Program will also develop and integrate information technologies needed to build a safer aviation system as well as providing information to assess situations and trends that might indicate unsafe conditions before they lead to accidents.

The Aviation Systems Capacity (ASC) Program was established as a separate program in FY 2000 to provide the leadership of the research and development activities necessary to address the growing problems of serious delay and inflexibility of the National Airspace System. This program supports the Office of Aero-Space Technology (OAT) enabling technology goal: "While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years". The ASC Program will continue to develop, validate and transfer advanced concepts, technologies, and operational concepts and their associated decision support tools, procedures, and hardware systems to maximize the capacity, efficiency, and flexibility of safe operations in the National Airspace System. Additionally, the introduction of new vehicle systems and classes will take full advantage of the improved modernized ATM system.

NASA is an active participant in the High Performance Computing and Communications (HPCC) program, and has pioneered the application of design and simulation software on parallel machines and developed the most widely accepted performance evaluation/tuning software for applications on parallel machines. In FY 2000, NASA will continue to support the Administration's Next Generation Internet (NGI) initiative, to increase the quality, security and certainty of Internet transmissions and to increase network capacity 1,000 times the capacity of the baseline. In FY 2000, NASA will also support the Administration's Information Technology initiative, focusing on research and technologies vital in five mission-critical areas: autonomous spacecraft and rovers; science data understanding; aviation operations; intelligent synthesis environment; and human exploration of space.

The Space Transportation Technology program leads NASA's efforts to develop advanced space transportation technologies critical to the economic, scientific, and technological competitiveness of the U.S. The program is developing new technologies aimed at reducing the cost of access to space and in-space transportation. The technologies targeted will reduce launch costs dramatically over the next decade, and increase the safety and reliability of current and future generation launch systems. In 1998, the

Reusable Launch Vehicle (RLV) program continued to pursue technology development, design and business planning activities in support of next-generation reusable systems, on the X-33 and X-34 flight demonstrators. The X-34 and X-33 are continuing fabrication and assembly **of** flight hardware. Funding for the RLV program in 1999 and 2000 is included to continue X-34 and X-33 technology development. hardware fabrication and test, in preparation for the flight of the technology demonstrators, which are scheduled to fly in 1999 and 2000 respectively.

The Future-X Pathfinder program completed its first competitive procurement cycle in December 1998. Boeing Corporation was selected to develop a modular orbital flight testbed, and 7 flight experiments were also chosen from ***6*** different bidders. These Future-X vehicles and flight experiments will demonstrate technologies to improve performance and reduce development, production and operating costs ***of*** future Earth-to-orbit and in-space transportation systems. Technologies tested through Future-X will help industry and NASA develop and build future generations **of** space launch vehicles, which are more advanced and cheaper than previous vehicles.

The Advanced Space Transportation Program (ASTP) **is** developing key technologies to dramatically reduce space transportation costs across the mission spectrum. ASTP will focus on technological advances with the potential of reducing launch costs beyond RLV goals, as well as on developing technology required to support NASA strategic needs that are not currently addressed by RLV. Future Space Launch Studies are underway to provide input to NASA and the Administration for a decision on whether to pursue an operational launch system to reduce NASA's launch costs.

In order to ensure national economic strength enhancements derived from NASA technology, NASA will continue to pursue a commercial technology mission concurrent to its aerospace mission. The commercial technology mission requires that each NASA program be carried out in a way that proactively involves the private sector from the onset, through a new way of doing business, to ensure that the technology developed will have maximum commercial potential. This mission requires NASA to impart, to the maximum extent possible, the benefits **of** its technological assets to the national economy and to use, to the maximum extent possible, and the strengths **of** the U.S. industrial base. In accomplishing this mission, NASA supports the development and transfer of technology. which leads to new commercial products and services.

The Commercial Technology Program achieves this new mission through one of NASA's crosscutting functions -- to provide aerospace products and capabilities to NASA customers. The Commercial Technology Program transfers NASA technology and technical expertise to commercial customers more effectively and efficiently while extending the technology, research and science benefits broadly to the public and commercial sectors. Some of the objectives are to proactively transfer technology through commercialization partnerships, and to integrate innovative approaches to strengthen **U.S.** competitiveness. Funding for the Commercial Technology Program continues to support development of commercial partnerships with industry. In FY 1999 and FY **2000.** emphasis will be on increasing commercial partnerships with industry and continued refinement of a technology and partnership database.

Academic Programs

Science and mathematics achievement is an integral element of the National Education Goals, and NASA's efforts in the education arena strongly support making U.S. students first in the world in science and mathematics achievement by the year 2000. NASA's programs at the pre-college, college and graduate levels use NASA's unique mission and results to capture and channel student interest in science, mathematics and technology, as well as enhance teacher and faculty knowledge and skills related to these subjects. At the undergraduate and graduate level, programs are geared to providing opportunities for students and faculty to participate in NASA-sponsored research activities at NASA field centers.

NASA has made a commitment to playing a leadership role in strengthening the capabilities of minority universities and to increasing opportunities for students at Historically Black Colleges and Universities and Other Minority Universities, primarily Hispanic-serving institutions and Tribal Colleges, to participate in and benefit from NASA's research and education programs. The FY 2000 budget request for the Minority University Research program continues this commitment through funding for initiatives that are under way.

Mission Communication Services

Included within the Science, Aeronautics and Technology appropriation is the support which is most directly related to NASA's science and aeronautics programs, including ground network support, mission planning for robotics spacecraft programs, suborbital mission support, support to aeronautics test programs, and technology development activities to improve the state of space communications technology. Efforts are ongoing to consolidate and streamline major support contract services in order to optimize space operations. On October 1, 1998, the Consolidated Space Operations Contract (CSOC) was competitively awarded to Lockheed-Martin Space Operations Company. This contract became operational on January 1, 1999, and is designed to maximize space operations resources by reducing systems overlap and duplication, and is expected to produce efficiencies and economies over the life of the contract which benefits all NASA programs.

MISSION SUPPORT

Safety, Mission Assurance, Engineering, and Advanced Concepts

NASA is committed to safety and mission success in all of its programs. The requested funding will continue forward-looking safety, mission success, and technology efforts by the Office of Safety and Mission Assurance (OSMA), the Office of the Chief Engineer (OCE), and the Office of the Chief Technologist (OCT). OSMA will develop and implement improved, tailored safety and mission assurance (SMA) policies, practices, and tools, including risk management, into all NASA programs. The OCE will provide a focus for NASA's engineering discipline, oversee applications, and improve NASA's engineering practices and capabilities. The OCT will evaluate advanced aerospace concepts for feasibility, benefits, and long-term technology requirements.

Space Communications Services

Funding for the operation, support and replenishment of NASA's Space Network is included in NASA's Mission Support appropriation. This program supports the operation of the Tracking and Data Relay Satellite (TDRS) System, the ground terminals at White Sands, New Mexico, and the NASA Control Center at the Goddard Space Flight Center. Funds for services provided to non-science users of the TDRSS are included under this program. The NASA Integrated Services Network are also funded by this appropriation. On October 1, 1998, the CSOC was competitively awarded to Lockheed-Martin Space Operations Company. This contract became operational on January 1, 1999, and is designed to maximize space operations resources by reducing systems overlap and duplication, and is expected to produce efficiencies and economies over the life of the contract which benefits all NASA programs. Procurement of the TDRSS spacecraft and associated launch vehicles currently remain outside the scope of the CSOC contract.

Research and Program Management

The NASA workforce is the foundation underpinning the successful achievement of NASA's goals. Funding for the salaries, travel support and other personnel expenses for the entire NASA workforce is included. Funding for activities that support the NASA workforce and physical plant is also included in Research and Program Management.

NASA's civil service workforce in FY 2000 continues the downsizing process initiated several years ago. Civil service expertise is essential to the timely, cost-effective and crucial research and development that NASA programs feature. NASA's budget request for FY 2000 continues the management policy of using buyouts (at selected Centers) to achieve reductions in planned levels of civil service staffing and support. Current planning supports a civil service workforce of less than 18,000 by the end of FY 2000. Training dollars are requested at levels sufficient to keep the workforce technically prepared to meet the challenges of NASA's diverse and highly technical programs.

Construction of Facilities

Funding is included for discrete projects to repair and modernize the basic infrastructure and institutional facilities, the minor repair, rehabilitation and modification of existing facilities, minor new construction projects, environmental compliance and restoration activities, the design of facilities projects, and the advanced planning related to future facilities needs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 2000 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	FY98 OPPLAN 9/29/98	FY99 OPPLAN 12/22/98	FY00 PRES BUDGET
HUMAN SPACE FLIGHT	**5559.5**	**5480.0**	--
SPACE STATION	2331.3	2304.7	--
RUSSIAN PROGRAM ASSURANCE	110.0	[53.0]	--
SPACE SHUTTLE	2912.8	2998.3	--
PAYLOAD AND UTILIZATION OPERATIONS	205.4	177.0	--
INTERNATIONAL SPACE STATION			**2482.7**
LAUNCH VEHICLES AND PAYLOAD OPERATIONS			**3155.3**
SPACE SHUTTLE			2986.2
PAYLOAD AND UTILIZATION OPERATIONS			169.1
SCIENCE, AERONAUTICS AND TECHNOLOGY	**5690.0**	**5653.9**	**5424.7**
SPACE SCIENCE	2043.8	2119.2	2196.6
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	214.2	263.5	256.2
EARTH SCIENCE	1417.3	1413.8	1459.1
AERO-SPACE TECHNOLOGY	1483.9	1338.9	1006.5
MISSION COMMUNICATION SERVICES	400.8	380.0	406.3
ACADEMIC PROGRAMS	130.0	138.5	100.0
MISSION SUPPORT	**2380.0**	**2511.1**	**2494.9**
SAFETY, MISSION ASSURANCE, ENGINEERING, AND ADVANCED CONCEPTS	37.8	35.6	43.0
SPACE COMMUNICATION SERVICES	194.2	185.8	89.7
RESEARCH AND PROGRAM MANAGEMENT	2025.6	2121.2	2181.2
CONSTRUCTION OF FACILITIES	122.4	168.5	181.0
INSPECTOR GENERAL	**18.2**	**20.0**	**20.8**
TOTAL BUDGET AUTHORITY	**13,647.7**	**13,665.0**	**13,578.4**
TOTAL OUTLAYS	**14,206.2**	**14,043.0**	**13,356.8**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES
SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS
(IN MILLIONS OF REAL YEAR DOLLARS)

	TOTAL	Human Space Flight	Science, Aero & Technology	Mission Support	Inspector General
FISCAL YEAR 1998					
VA-HUD INDEPENDENT AGENCIES APPROPRIATIONS ACT, FY 1998 (P.L. 105-65)	**13,648.0**	**5506.5**	**5690.0**	**2433.2**	**18.3**
TRANSFER FROM STATE DEPARTMENT (P.L. 105-119)	**0.2**			0.2	
1998 SUPPLEMENTAL APPROPRIATIONS AND RESCISSIONS ACT (P.L. 105-174) APPROPRIATIONS TRANSFER AUTHORITY	**0.0**	53.0		-53.0	
LAPSE OF FY 1998 UNOBLIGATED FUNDS	**-0.5**			-0.4	-0.1
TOTAL FY 1998 BUDGET PLAN	**13,647.7**	**5,559.5**	**5,690.0**	**2,380.0**	**18.2**
FISCAL YEAR 1999 REQUEST	**13,465.0**	**5,511.0**	**5,457.4**	**2,476.6**	**20.0**
VA-HUD INDEPENDENT AGENCIES APPROPRIATIONS ACT, FY 1999 (P.L. 105-276) AS PASSED BY CONGRESS, DIRECTION INCLUDED IN CONFERENCE REPORT H.R. 105-769	**200.0**	-31.0	196.5	34.5	
TOTAL FY 1999 BUDGET PLAN	**13,665.0**	**5,480.0**	**5,653.9**	**2,511.1**	**20.0**

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

DISTRIBUTION OF PROGRAM AMOUNT BY INSTALLATION
(Thousands of Dollars)

	International Space Station			Launch Vehicles and Payload Operations			Science, Aeronautics and Technology		
	1998	1999	2000	1998	1999	2000	1998	1999	2000
Johnson Space Center	2,135,700	1,876,000	2,011,700	1,720,406	1,772,600	1,783,500	94,820	119,177	113,772
Kennedy Space Center	94,100	108,300	114,100	209,358	230,300	249,900	245,646	319,224	265,942
Marshall Space Flight Center	150,200	222,000	215,000	1,113,568	1,105,300	1,067,100	686,553	612,331	484,851
Stennis Space Center	0	0	0	47,216	33,300	35,600	60,890	79,146	41,469
Ames Research Center	20,900	41,000	61,100	1,152	2,200	1,600	381,594	381,582	368,397
Dryden Flight Research Center	0	0	0	5,800	4,000	4,000	140,327	121,634	134,598
Langley Research Center	7,000	4,300	2,900	352	200	200	418,067	359,622	270,759
Glenn Research Center	30,600	30,500	49,900	750	0	0	374,334	322,308	254,322
Goddard Space Flight Center	800	0	0	12,469	13,300	8,800	2,048,068	2,019,656	1,973,983
Jet Propulsion Laboratory	600	5,600	11,000	102	100	100	1,077,650	1,130,402	1,348,663
Headquarters	1,400	17,000	17,000	7,027	14,000	4,500	162,051	188,818	167,944
TOTAL NASA	2,441,300	2,304,700	2,482,700	3,118,200	3,175,300	3,155,300	5,690,000	5,653,900	5,424,700

	Mission Support			Total		
	1998	1999	2000	1998	1999	2000
Johnson Space Center	342,525	367,570	363,200	4,293,451	4,135,347	4,272,172
Kennedy Space Center	248,364	296,775	279,480	797,468	954,599	909,422
Marshall Space Flight Center	379,988	391,570	360,115	2,330,309	2,331,201	2,127,066
Stennis Space Center	49,637	57,565	60,935	157,743	170,011	138,004
Ames Research Center	179,053	188,735	193,999	582,699	613,517	625,096
Dryden Flight Research Center	61,820	63,375	67,970	207,947	189,009	206,568
Langley Research Center	226,182	232,970	238,323	651,601	597,092	512,182
Glenn Research Center	261,368	215,480	220,523	667,052	568,288	524,745
Goddard Space Flight Center	411,012	433,610	405,130	2,472,349	2,466,566	2,387,913
Jet Propulsion Laboratory	23,478	22,080	21,200	1,101,830	1,158,182	1,380,963
Headquarters	192,877	238,130	278,025	363,355	457,948	467,469
Undistributed:						
Construction of Facilities: Various locations	3,721	3,240	6,000	3,721	3,240	6,000
Inspector General				18,152	20,000	20,800
TOTAL NASA	2,380,025	2,511,100	2,494,900	13,647,677	13,665,000	13,578,400

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

ADMINISTRATIVE PROVISIONS

Notwithstanding the limitation on the availability of funds appropriated for "International space station," "Launch vehicles and payload operations," "Science, aeronautics and technology", or "Mission support" by this appropriations Act, when any activity has been initiated by the incurrence of obligations for construction of facilities as authorized by law, such amount available for such activity shall remain available until expended. This provision does not apply to the amounts appropriated in "Mission support" pursuant to the authorization for repair, rehabilitation and modification of facilities, minor construction of new facilities and additions to existing facilities, and facility planning and design.

Notwithstanding the limitation on the availability of funds appropriated for "International space station," "Launch vehicles and payload operations," "Science, aeronautics and technology", or "Mission support" by this appropriations Act, the amounts appropriated for construction of facilities shall remain available until September 30, [2001] *2002*.

Notwithstanding the limitation on the availability of funds appropriated for "Mission support" and "Office of Inspector General", amounts made available by this Act for personnel and related costs and travel expenses of the National Aeronautics and Space Administration shall remain available until September 30, [1999] *2000* and may be used to enter into contracts for training, investigations, cost associated with personnel relocation, and for other services, to be provided during the next fiscal year.

NASA shall develop a revised appropriation account structure for submission in the fiscal year 2001 budget request consisting of the "Human Space Flight" account; the "Science, Aeronautics and Technology" account and the "Office of the Inspector General" account. The accounts shall each include the planned full costs (direct and indirect costs) of NASA's related activities and allow NASA to shift civil service salaries, benefits and support within and/or among accounts, as required, for the safe, timely and successful accomplishment of NASA missions.

(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPROPRIATION LANGUAGE AS PROPOSED BY THE ADMINISTRATION

HUMAN SPACE FLIGHT

For necessary expenses, not otherwise provided for, in the conduct and support of human space flight research and development activities, including research, development, operations, and services; maintenance; construction of facilities including repair, rehabilitation, and modification of real and personal property, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,511,000,000] $5,638,000,000, to remain available until September 30, [2000] 2001.

For necessary expenses of the International Space Station, to become available on October 1 of the fiscal year specified and remain available for that and the following fiscal year, as follows; for fiscal year [2000, $2,134,000,000]; for fiscal year 2001, [$1,933,000,000] $2,328,000,000; for fiscal year 2002, [$1,766,000,000] $2,091,000,000; for fiscal year 2003, [$1,546,000,000] $1,721,000,000; and for fiscal year 2004, [$350,000,000] $1,573,000,000. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)*

APPROPRIATION LANGUAGE AS PROPOSED BY 105-276

INTERNATIONAL SPACE STATION

For necessary expenses, not otherwise provided for, in the conduct and support of the International Space Station activities, including research, development, operations, and services; maintenance; construction of facilities including repair, rehabilitation, and modification of real and personal property, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, $2,482,700 to remain available until September 30, 2001.

For necessary expenses of the International Space Station, to become available on October 1 of the fiscal year specified and remain available for that and the following fiscal year, as follows: for fiscal year 2001, $2,328,000,000; for fiscal year 2002, $2,091,000,000; for fiscal year 2003, $1,721,100,000; and for fiscal year 2004, $1,573,000,000. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)*

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

For necessary expenses, not otherwise provided for, in the conduct and support of launch vehicles and payload operations activities, including research, development, operations, and services; maintenance; construction of facilities including repair, rehabilitation, and modification of real and personal property, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, $3,155,300, to remain available until September 30, 2001. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

SCIENCE, AERONAUTICS AND TECHNOLOGY

For necessary expenses, not otherwise provided for, in the conduct and support of science, aeronautics and technology research and development activities, including research, development, operations, and services; maintenance; construction of facilities including repair, rehabilitation, and modification of real and personal property, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,653,900,000] *$5,424,700,000*, to remain available until September 30, [2000] 2001. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Acts, 1999.)*

MISSION SUPPORT

For necessary expenses, not otherwise provided for, in carrying out mission support for human space flight programs and science, aeronautical, and technology programs, including research operations and support; space communications activities including operations, production and services; maintenance; construction of facilities including repair, rehabilitation, and modification of facilities, minor construction of new facilities and additions to existing facilities, facility planning and design, environmental compliance and restoration, and acquisition or condemnation of real property, as authorized by law; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by 5 U.S.C. 5901-5902; travel expenses; purchase, lease, charter, maintenance, and operation of mission and administrative aircraft; not to exceed $35,000 for official reception and representation expenses; and purchase (not to exceed 33 for replacement only) and hire of passenger motor vehicles; [$2,511,100,000] *$2,494,900,000*, to remain available until September 30, [2000] *2001*. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)*

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the Inspector General Act of 1978, as amended, [$20,000,000] *$20,800,000*. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

The FY 2000 multi-year budget estimate is submitted in accordance with the NASA FY 1989 Authorization Law (P.L. 100-685).

	1998 OPLAN 9/29/98	1999 OPLAN 12/22/98	2000 PRES BUDGET	2001	2002	2003	2004
INTERNATIONAL SPACE STATION	2,441.3	2,304.7	2,482.7	2,328.0	2,091.0	1,721.1	1,573.0
SPACE STATION	2,331.3	2,304.7	2,482.7	2,328.0	2,091.0	1,721.1	1,573.0
US/RUSSIAN COOPERATIVE PROGRAM	110.0						
LAUNCH VEHICLES AND PAYLOAD OPERATIONS	3,118.2	3,175.3	3,155.3	3,216.0	3,198.5	3,203.7	3,209.2
SPACE SHUTTLE	2,912.8	2,998.3	2,986.2	3,033.1	3.014.0	2,984.0	2,984.0
PAYLOAD UTILIZATION AND OPERATIONS	205.4	177.0	169.1	182.9	184.5	219.7	225.2
SCIENCE, AERONAUTICS AND TECHNOLOGY	5,690.0	5,653.9	5,424.7	5,657.3	5,781.3	6,141.0	6,248.6
SPACE SCIENCE	2,043.8	2,119.2	2,196.6	2,346.8	2,439.4	2,634.4	2,851.3
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	214.2	263.5	256.2	265.2	263.2	263.2	278.5
EARTH SCIENCE	1,417.3	1,413.8	1,459.1	1,462.8	1,420.5	1,373.0	1,424.4
AERO-SPACE TECHNOLOGY	1,483.9	1,338.9	1,006.5	950.4	981.6	1,013.6	998.6
MISSION COMMUNICATION SERVICES	400.8	380.0	406.3	382.1	296.6	296.8	265.3
ACADEMIC PROGRAMS	130.0	138.5	100.0	100.0	100.0	100.0	100.0
FUTURE PLANNING (SPACE LAUNCH)				150.0	280.0	460.0	330.0
MISSION SUPPORT	2,380.0	2,511.1	2494.9	2530.3	2665.8	2663.8	2698.8
SAFETY, MISSION ASSURANCE, ENGINEERING AND ADVANCED CONCEPTS	37.8	35.6	43.0	45.0	49.0	49.0	49.0
SPACE COMMUNICATION SERVICES	194.2	185.8	89.7	109.3	174.2	89.5	35.9
RESEARCH AND PROGRAM MANAGEMENT	2,025.6	2,121.2	2,181.2	2,195.0	2,261.6	2,344.3	2,432.9
CONSTRUCTION OF FACILITIES	122.4	168.5	181.0	181.0	181.0	181.0	181.0
INSPECTOR GENERAL	18.2	20.0	20.8	20.8	20.8	20.8	20.8
TOTAL	13,647.7	13,665.0	13,578.4	13,752.4	13757.4	13,750.4	13,750.4

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTERNATIONAL SPACE STATION

FISCAL YEAR 2000 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

The International Space Station (ISS) is a key component of NASA's Human Exploration and Development of Space (HEDS) Enterprise, which has as its ultimate mission to open the space frontier by exploring, using and enabling the development of space. The goal of the International Space Station (ISS) is to support activities requiring the unique attributes of humans in space and establish a permanent human presence in Earth orbit. In addition, the ISS program activities support the four major goals of the HEDS enterprise which are: (1) Increase human knowledge of nature's processes using the space environment; (2) Explore the solar system; (3) Achieve routine space travel; and (4) Enrich life on Earth through people living and working in space.

STRATEGY FOR ACHIEVING GOALS

As we expand our capabilities for allowing humans to live and work continuously in space, we are transitioning our research from the Shuttle-borne Spacelab and the conduct of joint space activities with Russia aboard the Mir, to the International Space Station.

Through the utilization of the Space Station, we will provide capabilities that enable the development of advanced space systems, technologies, and materials. In providing these capabilities, we will ensure that our workforce, our most important resource, will have management support to meet operational and future program requirements through career development training and employee recognition programs.

Recognizing the national benefits derived from past space activities, we will continue to emphasize the ISS program's contribution to the national community. These contributions include science and engineering educational opportunities for our youth, collaborative relationships with industry, and improved quality of life through advanced technology, provided both directly to the private sector and through "spinoffs". As we develop and build the ISS, we are actively seeking oppoortunities to reduce operational costs, improve performance on development projects and to selectively enhance capabilities to meet customer needs.

ISS achievements in the exploration and development of space will pave the way for enhancing our nation's leadership in expanding human presence in space. The success of the ISS in achieving Human Exploration and Development and Space goals and objectives will play a central role in leading our Nation to future discoveries and technological advances that will benefit us all.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTERNATIONAL SPACE STATION

FISCAL YEAR 2000 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1998	FY 1999	FY 2000
INTERNATIONAL SPACE STATION	**2,441.3**	**2,304.7**	**2,482.7**
SPACE STATION	2,331.3	2,304.7	2,482.7
US/RUSSIAN COOPERATION	110.0	--	--

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTERNATIONAL SPACE STATION

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

		BUDGET PLAN	
	FY 1998	FY 1999	FY2000
INTERNATIONAL SPACE STATION	--	.1	.1
SPACE STATION	--	.1	.1
US/RUSSIAN COOPERATION	--	--	--

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

DISTRIBUTION OF INTERNATIONAL SPACE STATION BY INSTALLATION
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Space Station	1998	2.331.300	2.034.100	94.100	142.600	0	20.200	0	7.000	30.600	700	600	1.400
	1999	2.304.700	1.876.000	108.300	222.000	0	41.000	0	4.300	30.500	0	5.600	17.000
	2000	2.482.700	2.011.700	114.100	215.000	0	61.100	0	2.900	49.900	0	11.000	17.000
U.S.-Russian Cooperative Program	1998	110.000	101.600	0	7.600	0	700	0	0	0	100	0	0
	1999	0	0	0	0	0	0	0	0	0	0	0	0
	2000	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL INTERNATIONAL SPACE STATION	1998	2.441.300	2.135.700	94.100	150.200	0	20.900	0	7.000	30.600	800	600	1.400
	1999	2.304.700	1.876.000	108.300	222.000	0	41.000	0	4.300	30.500	0	5.600	17.000
	2000	2.482.700	2.011.700	114.100	215.000	0	61.100	0	2.900	49.900	0	11.000	17.000

INTERNATIONAL SPACE STATION*

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT | **SPACE STATION**

SUMMARY OF RESOURCES REQUIREMENTS**

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Vehicle	1,604,800	1,034,000	890,100	ISS 1-5
Operations Capability	500,200	685,900	850,200	ISS 1-17
[Construction of Facilities included]	[--]	[1,200]	[--]	
Research	226,300	336,500	394,400	ISS 1-25
Russian Program Assurance	[110,000]	248,300	200,000	ISS 1-39
Crew Return Vehicle	--	--	148,000	ISS 1-45
Total	2,331,300	2,304,700	2,482,700	

Distribution of Program Amount by Installation

	FY 1998	FY 1999	FY 2000
Johnson Space Center	2,034,100	1,876,000	2,011,700
Kennedy Space Center	94,100	108,300	114,100
Marshall Space Flight Center	142,600	222,000	215,000
Ames Research Center	20,200	41,000	61,100
Langley Research Center	7,000	4,300	2,900
Glenn Research Center	30,600	30,500	49,900
Goddard Space Flight Center	700	--	--
Jet Propulsion Laboratory	600	5,600	11,000
Headquarters	1,400	17,000	17,000
Total	2,331,300	2,304,700	2,482,700

* The Space Station was funded in the Human Space Flight appropriation account in FY 1998 and FY 1999. The FY 1999 appropriations act directed NASA to submit the International Space Station as a separate appropriation account in the FY 2000 budget.

** Summary adjusted to reflect the effect of restructured budget in FY 2000, and prospective reallocations to the FY 1999 operating plan. The December 22, 1998 operating plan includes $53 million for Russian Program Assurance (RPA) for FY 1999. This budget assumes additional reallocations of $195.3 million from Vehicle to RPA in FY 1999.

PROGRAM GOALS

The goal of the International Space Station (ISS) is to support activities requiring the unique attributes of humans in space and establish a permanent human presence in Earth orbit. It provides a long-duration habitable laboratory for science and research activities which allow investigation of the limits of human performance, vastly expand human experience in living and working in space, and provide the capability to encourage and enable commercial development of space. The ISS will provide a capability to perform unique, long duration, space-based research in cell and developmental biology, plant biology, human physiology, fluid physics, combustion science, materials science and fundamental physics. ISS will also provide a unique platform for making observations of the Earth's surface and atmosphere, the sun, and other astronomical objects. The experience and dramatic results obtained from the use of the ISS will guide the future direction of the Human Exploration and Development of Space Enterprise, one of NASA's key strategic areas. The International Space Station is key to NASA's ability to fulfill its mission to explore, use, and enable the development of space for human enterprise.

STRATEGY FOR ACHIEVING GOALS

The ISS will be a laboratory in low Earth orbit on which American and international crews will conduct unique scientific and technological investigations in a microgravity environment. Establishing a permanent human presence in space, which the ISS makes possible, remains one of NASA's highest priorities. The Space Station is unique because it will provide the world with an unparalleled laboratory and habitable international outpost in space. The schedule for the current design emphasizes an early permanent crew capability that provides an advanced research facility for use by international crews for extended duration missions. Therefore, early in the on-orbit assembly of the program, the Space Station will provide the capability to stimulate new technologies, enhance industrial competitiveness, further commercial space enterprises, and add greatly to the storehouse of scientific knowledge.

The ISS is the culmination of the space station "Freedom" redesign work begun in FY 1993 to meet the President's goal to reduce program costs while still providing significant research capabilities.

The baseline program content includes ISS vehicle development, operations capability, and research, and has been expanded to include ongoing contingency activities in Russian program assurance, and development of a crew return vehicle. Extensive coordination with the user community is well underway, with payload facilities development and research and technology activities being coordinated with the Office of Life and Microgravity Sciences and Applications (OLMSA), the Office of Earth Science (OES) and the Office of Space Science (OSS). A plan for transition of utilization responsibilities back to the research offices once payload facilities are operational will be prepared later this year.

International participation in the Space Station program was initiated in 1984 with invitations issued by President Reagan to Europe, Japan and Canada. With the U.S. playing the lead role, the international partnership invited Russia to participate in the program in 1993. As a result, Space Station cooperating agencies now include NASA, the Russian Space Agency (RSA), the Canadian Space Agency (CSA), the European Space Agency (ESA), and the National Space Development Agency of Japan (NASDA). International participation in the program has significantly enhanced the capabilities of the ISS. Through FY 1998, the CSA, ESA and NASDA have invested nearly $4.5 billion for design and development, and anticipate a total expenditure of $10 billion. In accordance with the terms of the agreements, the U.S. and our international partners will share the total available resources and the common costs for operations. The ISS represents an unprecedented level of international cooperation.

Additionally, there are several bilateral agreements between NASA and other international agencies. An agreement with ESA provides early research opportunities to them in exchange for provision of research equipment to the U.S. Another agreement with ESA provides the U.S. with Nodes 2 and 3 as an offset for the Shuttle launch for the Columbus Orbital Facility (COF). A similar Agreement in Principle with NASDA provides a Centrifuge, Centrifuge Accommodation Module (CAM), and Life Sciences Glovebox as an offset for the Shuttle launch of the Japanese Experiment Module (JEM). NASA and the Italian Space Agency have an agreement for Italy's provision of three Multi-Purpose Logistics Modules (MPLMs) in exchange for research opportunities. The Brazilian Space Agency (AEB) has become a participant in the U.S. ISS program as well, by helping fulfill a portion of U.S. obligations to the ISS program in exchange for access to the U.S. share of ISS resources.

Development of the Space Station program is being conducted in a phased approach. The initial phase, which was successfully concluded in 1998, included nine Shuttle-Mir docking missions. The goals of this initial phase were to develop and demonstrate joint mission procedures with Russia, to gain valuable experience to reduce technical risk during International Space Station construction, and to provide early opportunities for extended scientific research.

The next phase of the program began with the launch of the U.S.-owned/Russian-launched Zarya propulsion module in November 1998, and concludes with the launch of the airlock on flight 7A. Permanent crew capability for three persons, and launch of the first crew to orbit is scheduled to occur in the second quarter of FY 2000, with the launch of the first Russian Soyuz spacecraft to ISS. Microgravity capability will be available in April 2000, with the outfitting of the U.S. laboratory. At completion of this phase in the fourth quarter of FY 2000, the Station configuration will include Unity (the first U.S. node), Discovery (the U.S. laboratory), pressurized mating adapters, power, airlock and multi-purpose logistics module (MPLM); Zarya, the Russian service module, and a Soyuz capsule; and the Space Station remote manipulator system (SSRMS) provided by Canada.

By the end of FY 2002 the Station configuration will include the U.S. Laboratory, the second U.S. node, truss segments, three solar arrays, the Japanese Experimental Module (JEM), and resupply/support vehicles. By the end of FY 2003, planned activities include the delivery to orbit of the two Russian research modules, the third U.S. Node, and the Cupola. By the end of FY 2004 the Station configuration will include the Columbus Orbital Facility (COF, ESA's pressurized module), the Crew Return Vehicle (CRV), the fourth Solar Array, the Centrifuge Accommodation Module (CAM)/Centrifuge and the habitation module. Delivery of the crew return vehicle and the final outfitting flight will mark the beginning of the permanent 6-member crew capability. Delivery of the habitation module will signal the initiation of the permanent 7-member crew capability. Routine logistics module launches to the Space Station will continue over the remaining life of the Station.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE STATION VEHICLE

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Flight hardware	1,461,000	853,200	748,700
Test, manufacturing and assembly	97,400	142,600	119,900
Transportation support	45,500	38,200	21,500
Flight technology demonstrations	900	--	--
Total	1,604,800	1,034,000	890,100

PROGRAM GOALS

Vehicle development of the International Space Station (ISS) will provide an on-orbit, habitable laboratory for science and research activities, including flight and test hardware and software, flight demonstrations for risk mitigation, and facility construction, shuttle hardware and integration for assembly and operation of the station, mission planning, and integration of Space Station systems.

STRATEGY FOR ACHIEVING GOALS

Responsibility for providing Space Station elements is shared among the U.S. and our international partners from Russia, Europe, Japan, and Canada. The U.S. elements include three nodes, a laboratory module, airlock, truss segments, four photovoltaic arrays, a habitation module, three pressurized mating adapters, unpressurized logistics carriers, and a cupola. Various systems are also being developed by the U.S., including thermal control, life support, navigation and propulsion, command and data handling, power systems, and internal audio/video. The U.S. funded elements also include the Zarya propulsion module provided by a Russian firm under the Boeing prime contract. Other U.S. elements being provided through bilateral agreements include the pressurized logistics modules provided by the Italian Space Agency, Nodes 2 and 3 provided by ESA, and the centrifuge accommodation module (CAM) and centrifuge provided by the Japanese.

Canada, member states of the European Space Agency (ESA), Japan, and Russia are also responsible for providing a number of ISS elements. Laboratory modules will be provided by the Japanese, ESA, and Russia. Canada will provide a remote manipulator system, vital for assembly of the station. The Russian Space Agency (RSA) is also providing significant ISS infrastructure elements including the Service Module (SM), science power platform, Soyuz crew transfer vehicle, Progress resupply vehicles, and universal docking modules.

The Boeing Company is the prime contractor for the design and development of U.S. elements of the International Space Station. It also has prime responsibility for integration of all U.S. and International Partner contributions and for assembly of the ISS. At their Huntington Beach site location (formerly McDonnell Douglas), Boeing is developing and building the integrated truss segments that support station elements and house essential systems, including central power distribution, thermal distribution and attitude control equipment. Other Boeing locations are also supporting the flight hardware build to mitigate capability shortfalls at Huntington Beach. Additionally major components of the communications and data handling, thermal control, and the guidance, navigation and control subsystems are being developed at Huntington Beach.

U.S. pressurized modules are being developed by Boeing at their Huntsville site location, and by ESA. The second flight to ISS, successfully conducted in December 1998, deployed Unity, a pressurized node which contains four radial and two axial berthing ports. Attached to the Node were two pressurized mating adapters (PMAs), which will serve as docking locations for the delivery of the U.S. Laboratory Module and the Multi-Purpose Pressurized Logistics Module. Under a bilateral agreement, ESA is providing Nodes 2 and 3 to the U.S. Node 2 is currently manifested for flight during the third quarter of FY 2002, the Cupola is manifested for flight during the third quarter of FY 2003, and Node 3 is manifested for flight during the fourth quarter of FY 2003. The final U.S. pressurized volume is the Habitation Module that will contain the galley, wardroom, waste management, water processing and other crew support functions necessary for human operations.

The power truss segments and power system, essential to the Station's housekeeping operations and scientific payloads, are being built by Boeing at their Canoga Park location (formerly Rocketdyne Division, Rockwell International). Four photovoltaic elements, each containing a mast, rotary joint, radiator, arrays, and associated power storage and conditioning elements comprise the power system.

The vehicle program also includes test, manufacturing and assembly support for critical NASA center activities and institutional support. These "in-line" products and services include: test capabilities; the provision of government-furnished equipment (GFE), including flight crew systems, environment control and life support systems, communications and tracking, and extravehicular activity (EVA) equipment; and, engineering analyses. As such, they support the work of the prime contractor, its major subcontractors and NASA system engineering and integration efforts.

Transportation support provides those activities that allow the Space Shuttle to dock with the Space Station. This budget supports development and procurement of two external Shuttle airlocks, and upgrade of a third airlock to full system capability, which were required for docking the Space Shuttle with the Russian Mir as well as for use with the Space Station. Other items in this budget include: the Shuttle Remote Manipulator System (RMS) and Space Shuttle mission training facility upgrades; development of a UHF communications system and a laser sensor; procurement of an operational space vision system; procurement of three docking mechanisms and Space Station docking rings; EVA/Extravehicular Mobility Units (EMU) services and hardware; and integration costs to provide analyses and model development.

Flight technology demonstrations were flown during Phase I, utilizing the Space Shuttle flights to the Russian Mir Space Station, in order to benefit the future operational phases of the ISS program. These demonstrations focused on areas of joint NASA/RSA developments where levels of technical or programmatic risk warranted additional verification, including: life support, the data processing system, automatic rendezvous and docking, vibration isolation in a microgravity environment, assembly and maintenance, loads and dynamics, contamination, radiation environment, micrometeoroid/orbital debris, and operational techniques development.

SCHEDULE & OUTPUTS

Completed Incremental Design Review (IDR)
Performed Stage Integration Reviews (SIR)

A series of incremental, cumulative reviews throughout the design phase to assure that system level requirements are properly implemented in the design, have tractability, and that hardware and software can be integrated to support staged assembly and operation. IDR #1 performed these functions for flights 1A/R through 6A. Subsequently, IDR #2 assessed design progress for flights 1A/R through 7A. IDR#2B assessed the entire Space Station assembly sequence.

IDRs have been replaced by Stage Integration Reviews (SIR), a more classical critical design review approach on a stage-by-stage basis which review groupings of flights with assembly hardware and functionality/performance linkages across the stage.

- Performed SIR 1 for flights through 2A (4th Qtr FY 1997)
- Performed SIR 2 for flights through 4A (1st Qtr FY 1998)
- Performed SIR 3 for flights through 6A (2nd Qtr FY 1998)
- Perform SIR 4 for flights through 4R (1st Qtr FY 1999)
- Perform SIR 5 for flights through UF-2 (1st Qtr FY 2000)

Prime Development Activity

NOTE: All activities listed are planning milestones, and are not contractual.

Flight 1A/R:
Zarya (FGB Energy Block)
(First Element Launch)
(Proton Launch Vehicle)
Planned (Rev B): Nov. 1997
Revised (Rev D Mod): Nov.1998
Completed November 1998

Self-powered, active vehicle; provides attitude control through early assembly stages; provides fuel storage capability after the service module is attached; provides rendezvous and docking capability.

- Completed factory ground testing of first flight unit (slip from 3rd Qtr FY 1997 to 2nd Qtr FY 1998)
- Completed flight software (slip from 3rd Qtr FY 1997 to 1st Qtr FY1998)
- Delivered FGB flight article to Baikanour (slip from 3rd Qtr FY 1997 to 2nd Qtr FY 1998)
- Installed solar arrays in FGB flight article (slip from 1st Qtr FY 1998 to 3rd Qtr FY 1998)
- Removed Zarya from storage and complete deconservation (1st Qtr FY 1999)
- Mated FGB to Launch Vehicle (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999)
- On-Orbit checkout, Service Module docking, fuel transfer (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999)
- Launch of the Zarya (1st Qtr FY 1999)

Flight 2A: Unity (Node 1), Pressurized Mating Adapters (PMA-1, PMA-2) Planned (Rev B): Dec. 1997 Revised (Rev D Mod): Dec. 1998 Completed December 1998	Initial U.S. pressurized element, launched with PMA-1, PMA-2, and 1 stowage rack; PMA-1 provides the interfaces between U.S. and Russian elements; PMA-2 provides a Space Shuttle docking location. • Completed Node STA static flight loads testing (slip from 4th Qtr FY 1997 to 1st Qtr FY 1998) • Completed mating of PMA-1 to Node (1st Qtr FY 1998) • Completed flight 2A Cargo Element Integration and Test (slip from 1st Qtr FY 1998 to 3rd Qtr FY 1998) • Completed mating of PMA-2 to Node (3rd Qtr FY 1998) • Space Shuttle Payload Integration and Test (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999) • Launch of Unity (flight 2A) (1st Qtr FY 1999)
Flight 2A.1 Logistics Planned (Rev C): Dec. 1998 Revised (Rev D Mod): 3rd Qtr FY 1999	Double Spacehab flight for logistics/resupply during early assembly; • Station Cargo Integration Review (SCIR) (2nd Qtr FY 1998) • Flight Operations Review (FOR) (2nd Qtr FY 1999) • Hardware on dock at KSC (2nd Qtr FY 1999) • Begin integration of critical spares into Spacehab Module (2nd Qtr FY 1999) • Delivery of Strela Cargo Crane to Integrated Cargo Carrier integration (2nd Qtr FY 1999) • Launch of flight 2A.1 (3rd Qtr FY 1999)
Flight 2A.2 Logistics Planned: 4th Qtr FY 1999	Double Spacehab flight for logistics during early assembly; equipment to outfit the service module. *This flight is currently in the planning stages.*
Flight 3A: Z1 Truss Segment, Control Moment Gyros (CMGs), PMA-3, KU-Band Planned (Rev B): July 1998 Revised (Rev D Mod): 1st Qtr FY 2000	Z1 Truss allows temporary installation of the P6 photovoltaic module to Node 1 for early U.S. based power; KU-band and CMGs support early science capability; PMA-3 provides a Space Shuttle docking location for the lab installation on flight 5A. • Completed CMG qualification and flight testing (2nd Qtr FY 1998) • Began assembly of 3A flight model DDCUs (slip from 1st Qtr FY 1997 to 1st Qtr FY 1998) • Z1 structure qualification completed (slip from 2nd Qtr FY 1997 to 3rd Qtr FY 1998) • Z1 modal and static qualification tests complete (slip from 4th Qtr FY 1997 to 2nd Qtr FY 1998) • PMA-3 on-dock at KSC (Slip from 4th Qtr FY 1997 to 2nd Qtr FY 1998) • KU-Band on dock at KSC (2nd Qtr FY 1998) • S-Band on dock at KSC (3rd Qtr FY 1998) • Z1 final assembly and test (4th Qtr FY 1998)

Flight 4A: P6 Truss segment, Photovoltaic Array, Thermal Control System (TCS) Radiators, S-Band Equipment Planned (Rev B): Nov. 1998 Revised (Rev D Mod): 1st Qtr FY 2000	This flight provides the first U.S. solar power via solar arrays and batteries, cooling capability and S-Band system activation • BGA to P6 Integ (3rd Qtr FY 1998) • IEA/Long Spacer ready for integration and test (4th Qtr FY 1998) • Z1/P6 on dock KSC for MEIT (4th Qtr FY 1998) • Qualification and flight model radiators delivered (1st Qtr FY 1999) • Solar Arrays on-dock KSC (2nd Qtr FY 1999) • Launch flight 4A (1st Qtr FY 2000)
Flight 5A: U.S. Laboratory, 5 Lab System Racks Planned (Rev B): Dec. 1998 Revised (Rev D Mod): 2nd Qtr FY 2000	Establishes initial U.S. user capability; launches with 4 system racks preintegrated; KU-band and CMGs are activated. • Complete flight 5A Stage Integration Review (slip from 4th Qtr FY 1997 to 3rd Qtr FY 1998) • Install 5A/6A Racks in Lab for testing (3rd Qtr FY 1998) • Complete lab racks, crew systems, closeouts, and hatch installation (slip from 1st Qtr FY 1998 to 1st Qtr FY 1999) • Lab on dock at KSC (1st Qtr FY 1999) • Deliver Command and Control and Guidance Navigation and Control Software to Lab (2nd Qtr FY 1999) • Launch of flight 5A (2nd Qtr FY 2000)
Flight 5A.1: MPLM flight module-1, 6 Lab System Racks, 1 Payload Rack Planned: 2nd Qtr FY 2000	Continues the outfitting of the U.S. Lab, with the launch of 6 system racks. This flight also represents the first use of science with the launch of the Human Research Facility (HRF) rack. It is also the first use of the Multi-Purpose Logistics Module (MPLM). • Complete MPLM Integration and Test (4th Qtr FY 1998) • MPLM on-dock at KSC (4th Qtr FY 1998) • Lab on dock at KSC (1st Qtr FY 1999) • Complete MPLM portion of MEIT (2nd Qtr FY 1999) • Integration of HRF Sub-racks into the HRF rack (3rd Qtr FY 1999 • HRF rack on-dock at KSC (1st Qtr FY 2000)

Flight 6A:
MPLM flight module-2, Canadian Remote Manipulator System, UHF
Planned (Rev B): January 1999
Revised (Rev D Mod): 3rd Qtr FY 2000

Continues U.S. lab outfitting with delivery of 2 stowage and 2 EXPRESS payload racks; UHF antenna provides space-to-space communication capability for U.S. based EVA; manifests Canadian SSRMS needed to perform assembly operations on later flights.

- Complete Stage Assessment Integration Review (slip from 4th Qtr FY 1997 to 2nd Qtr FY 1998)
- Complete weld of MPLM FM2 Structure (3rd Qtr FY 1998)
- SSRMS and RWS Software complete (1st Qtr FY 1999)
- SSRMS On-dock KSC (2nd Qtr FY 1999)
- Begin integration of Spacelab Logistics Pallet (SLP) Cargo Element (slip from 2nd Qtr FY 1998 to 3rd Qtr FY 1999)
- Complete Integration and Test of MPLM FM2 (3rd Qtr 1999)
- MPLM FM2 On-dock KSC (3rd Qtr 1999)
- MEIT I Complete (3rd Qtr FY 1999)
- Launch of flight 6A (3rd Qtr FY 2000)

Flight 7A:
Airlock, HP Gas
Plan (Rev B): April 1999.
Actual (Rev D Mod): 4th Qtr FY 2000

Launches the airlock and installs it on orbit. The addition of the airlock permits ISS-based EVA to be performed without loss of environmental consumables such as air.

- Began Airlock Integration/A&CO (4th Qtr FY 1998)
- Element level testing complete (3rd Qtr FY 1999)
- Airlock on dock at KSC (3rd Qtr FY 1999)
- Complete SLP integration (3rd Qtr FY 1999)
- Launch flight 7A (4th Qtr FY 2000)

Flight 7A.1
MPLM, SLP pallet
Planned (Rev B): Nov. 1999
Revised (Rev D Mod): 4th Qtr FY 2000

Logistics and utilization mission delivering resupply/return stowage racks resupply stowage platforms, and two EXPRESS payload racks. This flight will carry critical spares as well as various resupply items.

- Turnover of EXPRESS racks to KSC (2nd Qtr FY 2000)
- Launch of MPLM FM1 (re-use) on flight 7A.1 (4th Qtr FY 2000)

Flight 8A:
S0 Truss, Mobile Transporter,
Plan (Rev B): June 1999
Revised (Rev D Mod): 2nd Qtr FY 2001

S0 is the truss segment that provides attachment and umbilicals between pressurized elements and truss mounted distributed systems/utilities. Mobile Transporter provides SSRMS translation capability along the truss.

- Complete S0 STA fabrication, assembly, and outfitting (1st Qtr FY 1999)
- Complete S0 STA structural testing (4th Qtr FY 1999)

- Complete S0 flight fabrication, assembly, and outfitting (3rd Qtr FY 1999)
- S0 on dock at KSC (3rd Qtr FY 1999)
- Complete S0 integrated testing (1st Qtr FY 2000)
- Complete Mobile Transporter flight article (2nd Qtr FY 1999)

Flight 9A:
S1 Truss, CETA Cart
Plan (Rev B): September 1999
Revised (Rev D Mod): 3rd Qtr FY 2001

S1 truss provides permanent active thermal control capability. Crew and Equipment Translation Aid (CETA) cart provides EVA crew translation capability along the truss.

- Complete second S-band string (3rd Qtr FY 1998)
- Radiators complete for S1 Integration (3rd Qtr FY 1999)
- Complete S1 STA fabrication, assembly, and outfitting (2nd Qtr FY 1999)
- Complete S1 STA testing (2nd Qtr FY 2000)
- Complete S1 flight fabrication, assembly, and outfitting (4th Qtr FY 1999)
- S1 on dock at KSC (4th Qtr FY 1999)
- Complete S1 integrated testing (1st Qtr FY 2000)

Non-Prime Development Activity

Global Positioning System (GPS)

Provides autonomous, real-time determination of Space Station's position, velocity, and attitude

- Delivered GPS Antenna Assembly (4th Qtr FY 1997)
- Deliver GPS Receiver/Processor (slip from 3rd Qtr FY 1997 to 1st Qtr FY 1999)

Extra-Vehicular Activity System

Provides Government Furnished Equipment (GFE), EVA unique tools, Orlan SAFER (Russian space suit), and EVA support equipment for the Space Station. Provides EVA development and verification testing. Provides for operation of the WETF/NBL and the maintenance of neutral buoyancy mockups to support Station EVA development activities.

- Deliver Crew Equipment Transfer Aid (CETA) Cart proto-flight unit (slip from 1st Qtr FY 1997 to 4th Qtr FY 1999)
- Deliver EVA Tool Storage Device (ETSD) for CETA Cart (1st Qtr FY 1998)
- Deliver ETSD for airlock (1st Qtr FY 1998)
- Deliver 1st 3 canisters for the Regenerable CO_2 System (2nd Qtr FY 1998)
- Deliver 1st Flight Regenerator for the Regenerable CO_2 System (3rd Qtr FY 1998)
- ORU Transfer Device (OTD) flight unit complete (1st Qtr FY 1999)

Flight Crew Systems	Provides flight and training hardware and provisions for food and food packaging development; housekeeping management; portable breathing apparatus; restraints and mobility aids; tools diagnostic equipment and portable illumination kit. • Completed 6A Operations and Personal Equipment CDR (1st Qtr FY 1997) • Delivered Restraints and Mobility Aids (1st Qtr FY 1997) • Completed CDR for portable illumination (2nd Qtr FY 1997) • Complete Stowage Tray Restraint CDR (slip from 2nd Qtr FY 1997 to TBD) • Complete production of tools and diagnostic flight hardware kit (slip from 1st Qtr FY 1998 to 3rd Qtr FY 1998) • Complete Personal Hygiene Kit PRR Preliminary/Program Requirements Review (2nd Qtr FY 1998) • Deliver Maintenance Workstation Kit, Portable Illumination, and Housekeeping Kit (4th Qtr FY 1998)
Airlock Service And Performance Checkout Unit	Provides flight servicing, performance unit, and certification unit, Russian space suit support hardware interface definition and documentation, test plans and reports, mockups, and thermal analysis. • Deliver certification unit hardware to airlock test article (Slip from 2nd Qtr FY 1997 to 3rd Qtr FY 1998) • Complete qualification unit testing and flight unit acceptance testing (slip from 4th Qtr FY 1997 to 3rd Qtr FY 1999)

ACCOMPLISHMENTS AND PLANS

FY 1998 activities focused on the buildup of ISS elements required for Phase 2/3 assembly of the International Space Station. These activities included:

- Modifications to the Zarya spacecraft, implemented under the U.S. Russian Cooperation and Program Assurance budget to accommodate SM uncertainties, have been completed. Testing on the Zarya was completed in May 1998, and it was in storage at the Baikonur launch site until August. The Zarya launched November 20th, 1998.

- The flight 2A activities in FY 1998 included Common Berthing Module acceptance testing, Cargo Element integration, and the completion of Space Station Processing Facility integration. Flight 2A launched December 4th, 1998.

- Flight 2A.1 was added to the assembly sequence in early FY 1998. Two elements, a Spacehab double module and an ICC (Integrated Cargo Carrier), are required to transport certain Spares hardware and the Russian Strela (cargo crane). Key 2A.1 activities in FY 1998 include a final manifest decision on the Russian Strela, as well as the manufacture and test of the spares hardware scheduled to fly on this flight.

- Flight 2A.2 was added to the assembly sequence in early FY 1999. This flight carries the same two elements, a Spacehab double module and an ICC as flight 2A.1. The hardware to be launched on this flight is still under review.

- In preparation for flight 3A, fabrication, assembly and qualification testing of the Z1 truss segment was completed. The Z1 truss segment has completed Z1/P6 integration testing. PMA-3 outfit and test was completed in mid-1998. Other major accomplishments in FY 1998 included the completion of qualification testing and the delivery of S-Band and Ku-Band flight hardware for Z1 truss integration. Set up for Multi-Element Integration Testing (MEIT) - Test Condition One began in the last quarter of FY 1998.

- Flight 4A launches the Integrated Equipment Assembly (IEA), Photovoltaic (PV) Array, Early External Active Thermal Control System (EEATCS), and the P6 truss segment. This flight provides the first U.S. solar power via solar arrays and batteries, cooling capability and S-Band system activation. Activities for flight 4A in FY 1998 included the completion of the fabrication and assembly of the P6 IEA. Outfitting and Z1/P6 integration testing was completed in the fourth quarter of FY 1998. Flight deliveries of the electrical ORUs have arrived at KSC for integration into the IEA.

- Structural test article testing and standoff/endcone installation for the U. S. Lab have been completed. 5A/5A.1 racks have been installed, and remaining Lab qualification hardware/software integration testing is continuing. The configured Lab Module arrived on-dock at KSC on November 16th, 1998, in preparation for MEIT that begins in March 1999.

- Flight 5A.1 was added to the assembly sequence in early FY 1999. This flight represents the first use of the Multi-Purpose Logistics Module (MPLM). The MPLM for flight 5A.1 has completed its integration and testing and has been delivered to KSC in preparation for MEIT. The Human Research Facility (HRF) Rack, which represents the first utilization for the ISS for science/experiments, is currently in assembly and is scheduled to be at KSC in the first quarter of FY 2000.

- The MPLM used on flight 6A is the second flight unit to be built. The structure for this unit is scheduled to be completed early in FY 1999. The SSRMS, which also flies on flight 6A, completed its acceptance review and is scheduled for delivery to KSC in the Spring of 1999. There are two EXPRESS payload racks scheduled to be launched on flight 6A. One of these racks is the first use of an Active Rack Isolation System (ARIS) EXPRESS rack. Both of the EXPRESS racks began their sub-rack integration and verification in FY 1998.

- The airlock, which flies on flight 7A, completed its Structural Static Test in early 1998. The Structural Modal Test was completed in May 1998. Airlock assembly and checkout began in the 4th Qtr of FY 1998. The airlock system racks were completed in FY 1998 and are ready to be integrated into the airlock for element level testing.

- Flight 7A.1 involves the re-use of MPLM FM1 to transport spares and resupply items as well as two additional EXPRESS racks. This flight is currently under review.

- Flight UF-1 also involves the re-use of a MPLM (FM2) to transport the Minus Eighty Degree Laboratory Freezer (MELFI) and the Microgravity Sciences Glovebox. The Spares Warehouse, which was added in FY 1998 to provide on-orbit stowage for critical spares, will also be transported.

- Primary Structure assembly for integrated truss structure S0, which is launched with flight 8A, was completed, and secondary structure assembly was started in early FY 1998. Effort in FY 1998 was focused on the sub-systems that are integrated into the S0 element. Qualification testing for the Mobile Transporter has started and is scheduled to complete in the second quarter of FY 1999.

- Flight UF-2 involves the use of an MPLM to transport the fifth EXPRESS Rack and Window Observation Research Facility (WORF). The Mobile Base System (MBS), which is used with the MT to provide a base for the arm, also rides in the Shuttle Cargo Bay. This flight is currently under review.

FY 1999 activities focused on the buildup of ISS elements required for Phase 2/3 assembly of the International Space Station. These activities included:

- The major program focus will be integrating and testing flight hardware and software to support the initial launches of the ISS. FY 1999 assembly activities began with the successful launch of the U.S. owned/Russian launched functional cargo block (Zarya) in November of 1998. Zarya is a self-sufficient orbital vehicle that will provide initial capabilities for propulsion, guidance, communication, electrical power and thermal control systems.

- The second assembly flight, flight 2A, launched Unity (Node 1), 1 stowage rack, and two pressurized mating adapters (PMA-1 & PMA-2) on the Space Shuttle in December. PMA-1 will provide a pressurized tunnel between the U.S. pressurized elements and the Russian modules. PMA-2 will provide a Shuttle docking location.

- Critical Spares to be flown on flight 2A.1 are scheduled to be delivered in the second quarter of FY 1999 for integration into the Spacehab module. Additionally, the Strela Cargo Crane and the ORU Transfer Device (OTD) are also being delivered for integration into the Integrated Cargo Carrier. Flight 2A.1 is planned to launch in the third quarter of FY 1999.

- Work done in preparation for flight 1R, scheduled to be launched in the fourth quarter of FY 1999, will include the completion of flight article testing, final software deliveries and final crew training. Flight 1R launches the SM that provides all the systems necessary for independent orbital operations and service as a habitat and laboratory.

- Flight 2A.2, planned to be launched in the 4th quarter of FY 1999, was added to the assembly sequence early in the fiscal year. This flight is currently in the planning stages.

- Flight 3A activities in FY 1999 include the completion of MEIT testing and Z1 truss outfitting in preparation for launch in the first quarter of FY 2000.

- Flight 4A activities in FY 1999 include the delivery and integration of major sub-systems including the Early External Active Thermal Control System (EEATCS) and Photovoltaic (PV) Arrays onto the P6. MEIT and P6 final assembly and test will be completed in the fourth quarter of FY 1999. Flight 4A launches in the first quarter of FY 2000.

- Flight 2R, in the first quarter of FY 2000, launches a Soyuz crew transfer vehicle, providing the Space Station with three-person human permanent presence capability.

- During FY 1999, flight 5A will go through extensive testing. MEIT being performed in the last three-quarters of FY 1999, and additional qualification testing at KSC will be completed in this year as well. FY 1999 also includes the completion and delivery of two major pieces of station software - GN&C software (Guidance, Navigation and Control) and Command and Control software.

- The MPLM, which arrived at KSC in FY 1998, will be mated to the Lab and undergo MEIT Testing in FY 1999. The HRF flight rack and its various sub-racks will go through fabrication, assembly, and testing in FY 1999.

- Flight 6A elements are also rigorously tested during FY 1999. The SSRMS, which arrives at KSC during FY 1999, and is mated with the Lab for MEIT testing in the third quarter of FY 1999. Hardware integration onto the SLP (Spacelab Logistics Pallet) begins in FY 1999 in preparation for launch in the third quarter of FY 2000.

- During FY 1999, the airlock, which will be flown on flight 7A, will complete its assembly and checkout and go through element level qualification testing. It will then be reconfigured and shipped to KSC. Once it arrives at KSC, it will undergo pre-integration and leak testing in preparation for launch late in FY 2000.

- The MPLM FM1 is re-used for flight 7A.1. This flight is currently under re-planning preparation for launch in the fourth quarter of FY 2000.

- FY 1999 activities for flight UF-1 include the completion of the MELFI and the Microgravity Sciences Glovebox.

- Many of the ORUs to be integrated on the S0 truss for flight 8A will complete qualification testing and the flight hardware will be delivered during FY 1999. The Mobile Transporter (MT), which is integrated on the S0 truss, will also go through rigorous testing prior to its integration onto the S0 truss segment. The S0 element will be delivered to KSC in the third quarter of FY 1999 where it will begin acceptance testing.

- In preparation for flight UF-2, Mobile Base System (MBS) testing will be completed and the unit shipped to KSC for MEIT 2 in the fourth quarter of FY 1999. EXPRESS Racks scheduled for this flight begin assembly in the fourth quarter of FY 1999.

FY 2000 consists of the launch of seven U.S. flights, two of which (5A and 7A) are considered the most complicated flights in the Space Station Program. Activities in preparation for these flights include:

- Flight 5A launches the U. S. laboratory (Discovery) and five-lab system racks for experiments in the second quarter of FY 2000. Shuttle Integration for this flight occurs in the first quarter of FY 2000. Activation of the Lab initiates U.S. user capability and also provides electrically powered attitude control with the activation of the Control Moment Gyroscopes.

- Flight 5A.1 will launch in the second quarter of FY 2000 with the MPLM. It will carry 6 system racks and an HRF rack for installation into the U.S. Lab.

- Flight 6A, in the third quarter of FY 2000, will launch with the MPLM. It will carry two payload racks for installation into the U.S. Lab, as well as stowage racks, and stowage platforms to carry logistics and re-supply items to orbit. Deployment of the UHF Antenna on this flight provides space-to-space communications capability for U.S.-based space walks. The Canadian SSRMS is also delivered on this flight, providing critical capability for assembly and operations on later flights.

- Flight 7A will launch the airlock and high-pressure gas orbital replaceable unit (ORUs), which are attached to the airlock. The airlock will be delivered to KSC in June 1999 and launched in the fourth quarter of FY 2000. The high-pressure gas assembly supports spacewalk operations and augments the Russian Service Module's gas resupply system.

- Activities for flight 7A.1 include the turnover of the EXPRESS rack to KSC in the second quarter of FY 2000 for sub-rack (experiment) integration. This activity supports a fourth quarter FY 2000 launch.

- The launch of UF-1 is scheduled for the first quarter of FY 2001, and is currently under review.

- FY 2000 activities for flight 8A, which launches in the second quarter of FY 2001, include acceptance testing and the completion of MEIT 2. Launch package integration and launch processing also occur in this year.

- UF2 is scheduled to launch in the second quarter of FY 2001. It will carry the MBS to be used in conjunction with the MT to provide a base for the SSRMS. This flight is currently under review.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE STATION OPERATIONS CAPABILITY

	FY 1998	FY1999	FY 2000
		(Thousands of Dollars)	
Operations capability & construction...	115,100	79,500	39,800
Vehicle operations..........	178,700	344,000	540,400
Ground operations..........	206,400	262,400	270,000
[Construction of Facilities included]	[--]	[1,200]	[--]
Total..........	500,200	685,900	850,200

PROGRAM GOALS

The first objective of the operations program is to provide for the safe, reliable and sustained operation of the Space Station as well as the ground operations required to plan, train, and fly the vehicle. The second major goal is to perform the operations in a simplified and affordable manner. This includes NASA's overall integration of distributed operations functions to be performed by each of the international partners in support of their elements. Space Station operations will rely on the infrastructure developed for the Space Shuttle, and the experience derived from the Shuttle-Mir program to develop efficient and effective operations. Finally, operations will facilitate the transition of the various elements of the International Space Station (ISS) vehicle program to the operations program.

STRATEGY FOR ACHIEVING GOALS

In order to increase efficiency and lower the cost of operations, vehicle and ground operations planning began early in the ISS development program. Streamlining and efficiencies with existing programs will be maximized.

Operations capability and construction provides for the development of a set of facilities, systems, and capabilities to conduct the operations of the Space Station. The work will be performed at the Kennedy Space Center (KSC) and the Johnson Space Center (JSC). KSC has developed launch site operations capabilities for conducting pre-launch and post-landing ground operations. JSC has developed space systems operation capabilities for conducting training and on-orbit operations control of the Space Station. Construction of the Neutral Buoyancy Laboratory (NBL) in Houston has been completed, and it is providing the capability for simultaneous EVA training of up to nine Space Station crewmembers at a time. The redesigned Space Station emphasizes multi-center and multi-program cooperation and coordination. At JSC a consolidated approach between Space Shuttle and Space Station minimizes duplicated effort and costs for command and control, as well as training. Crew training will be based on a detailed risk analysis to determine the optimum failure response training profile. Therefore, training will be knowledge- and proficiency-based rather than driven by timeline and detailed procedures rehearsal.

Space Station vehicle operations provides systems engineering and integration to sustain the specification performance and reliability of Space Station systems, logistics support for flight hardware and launch site ground support equipment, configuration management, and any associated procurement activity. Sustaining engineering will be performed, and will be consolidated at the Johnson Space Center (JSC) to allow all flight hardware and software to be handled under a single contract. Maintenance and repair costs continue to be minimized by the application of logistics support analysis to the design, resupply/return and spares procurement processes. Flight hardware spares and repair costs will continue to be controlled by establishing a maintenance and repair capability that effectively utilizes Kennedy Space Center (KSC) and original equipment manufacturers or other certified industry repair resources.

Ground operations provides command and control, training, operations support and launch site processing. A unified command and control center for the Space Station includes the Mission Control Center-Houston (MCC-H) and the Mission Control Center-Moscow (MCC-M) at Kaliningrad. As the flight elements from Europe, Japan and Canada become operational, their respective ground operations functions will be integrated by NASA into the unified command and control architecture. The MCC-H will be the prime site for the planning and execution of integrated system operations of the Space Station. Communication links from both Moscow and Houston will support control activities, using the Tracking and Data Relay Satellite System (TDRSS) system and the Russian communication assets.

Flight controllers are being trained to operate the Space Station as a single integrated vehicle, with full systems capability in the training environment. Crewmembers are being trained in the NBL and Space Station Training Facility (SSTF) on systems, operations, and other activities expected during a mission. Part-task and full hardware mockups and simulators are being used to provide adequate training for the crew prior to flight. Integrated training, consolidation of payload and systems training facilities, the concept of proficiency-based learning, and onboard training will increase the efficiency of the overall training effort.

Ground operations support provides analysis systems definition, development, and implementation to ensure that a safe and operationally viable vehicle is delivered and can be maintained. Functions include the following: vehicle design participation and assessment, operations product development, ground facility requirements and test support, ground display and limited applications development, resource planning, crew systems and maintenance, extravehicular activity (EVA), photo/TV training, operations safety assessments, medical operations tasks, mission execution and systems performance assessment, and sustaining engineering.

Cargo integration support provides accurate, timely, and cost effective planning and layout of cargo stowage items, analytical analysis of cargo/transport systems compatibility, and physical integration of cargo items into the transport carriers and on-orbit ISS stowage systems.

Launch site processing begins prior to the arrival of the flight hardware at KSC with requirement definition and processing planning. Upon arrival at KSC, the flight hardware will undergo various processes, dependent upon the particular requirements for that processing flow. These processes may include: post delivery inspection/verification, servicing, interface testing, integrated testing, close-outs, weight and center of gravity measurement, and rack/component to carrier installation.

SCHEDULE & OUTPUTS

Space Station Training Facility (SSTF)

Primary facility for space systems operations training and procedures verification.

- SSTF Initial Ready for Training (RFT) for flight 5A (slip from 4th Qtr FY 1998 to 4th Qtr FY 1999)
- SSTF Final RFT for flight 5A (1st Qtr FY 2000)
- SSTF Final RFT for flight 2A (4th Qtr FY 1998)
- SSTF Initial RFT for flight 6A (1st Qtr FY 2000)
- SSTF Final RFT for flight 6A (2nd Qtr FY 2000)
  *Flights beyond 6A TBD for SSTF

Integrated Planning System (IPS)

Provides planning and analysis tools for pre-increment and real-time operations systems supporting trajectory/flight design, timelines, resource utilization, onboard systems, performance analyses systems operation data file procedures and control, maintenance operations, inventory and logistics planning, robotics analysis, and procedures development.

- Complete ISS MOD Avionics Reconfiguration System (IMARS) development (2nd Qtr FY 1998)
- Complete IPS development (3rd Qtr FY 1999)

Mission Control Center

Facility providing integrated command and control capabilities and support to real-time increment operations.

- Completed Software Verification Facility (SVF) integration test for flights 2A-4A (slip from 2nd Qtr FY 1997 to 2nd Qtr FY 1998)
- Mission Control Center - Houston Configuration Complete for 2A. (slip from 3rd Qtr FY 1997 to 1st Qtr FY 1999)
- Mission Control Center ready to support use of ICM (slip from 3rd Qtr FY 1998 to 2nd Qtr FY 1999)
- Delivery to support flight 5A ISS Command and Control Capability (slip from 4th Qtr FY 1998 to 1st Qtr FY 1999)
- Complete backup control center (control center development complete) (3rd Qtr FY 1999)
- MCC RFT for UF-1 (3rd Qtr FY 2000)

Complete MCC-H/Space Station Training Facility (SSTF) integrated ops training capability Plan: October 1997 Actual: October 1997	Supports the training schedule to train ground crews for real-time operations of the Space Station vehicles.
Baseline SSP 50234, Sustaining Engineering Implementation Plan Plan: January 1998 Actual: April 1998	Required to ensure NASA and its contractors are providing proper skills, tools, processes, and facilities for supporting delivered flight hardware and software.
Baseline SPIP Vol. 10, Sustaining Engineering Plan: January 1998 Actual: June 1998	Standard Program Implementation Plan Volume 10 provides guidance on requirements to ensure provision of proper skills, tools, processes, and facilities for supporting delivered flight hardware and software.
Definitize Sustaining Engineering Contract Mod Plan: March 1998 Actual: December 1998	Required to ensure prime contractor support for delivered ISS flight hardware and software is in place.
Demonstrate MCC-H to MCC-M Command Support Capability Plan: March 1998 Actual: November 1998	Development of the Mission Control Center - Houston (MCC-H) to Mission Control Center - Moscow (MCC-M) command capability. This requirement was met upon completion of end-to-end testing.
Publish MIM 98-1 Plan: April 1998 Revised: December 1998	Annual update of the multi-increment manifest (MIM) covering Program multi-lateral vehicle traffic and crew rotation plan through the assembly period. This update incorporates the Rev. D Modified assembly sequence.
Begin MCC-H ISS flight-following mode with flight 1A/R and 2A Plan: June 1998 Actual: November 1998	The Mission Control Center - Houston (MCC-H) is in a flight-following mode of operations until flight 5A, when NASA takes over primary real-time command and control of the ISS.

Baseline Increment Definition & Requirements Document (IDRD) PP#3 (Preliminary) Plan: April 1998 Actual: April 1998	The IDRD includes requirements and resource allocations for Planning Period 3 that covers the 2000 time frame.
Baseline Increment Definition And Requirements Document (IDRD) for Increment 4 Plan: May 1999 Actual:	Baselining the ISS increment in the Increment Definition and Requirements Document officially initiates increment specific Product and training Development. This typically occurs at 18 months in advance of increment operations. The IDRD is baselined after Multilateral Increment Training Plan is baselined and a detailed ISS crew training plan is developed
SSTF Dual String Capability Plan: June 1999 Actual:	The Space Station Training Facility is a training replica of the ISS on the ground. Dual String Capability will allow two training sessions to be run simultaneously, one of which can be integrated with the Mission Control Center for flight controller training
Baseline Increment Definition And Requirements Document (IDRD) for Increment 5 Plan: August 1999 Actual:	Baselining the ISS increment in the Increment Definition and Requirements Document Officially initiates increment specific Product and training Development. This typically occurs at 18 months in advance of Increment operations. The IDRD is baselined after Multilateral Increment Training Plan is baselined and a detailed ISS crew training plan is developed
Integrated Planning System Final Development Release Plan: September 1999 Actual:	The Integrated Planning System provides the planning and training analysis tools required to support long range mission and vehicle change assessments, mission design, mission and increment planning, pre-mission and contingency analysis, and direct mission support.
Conduct Increment Operations Review for Increment 1 Plan: Sept 1999 Actual:	Formal program review of integrated operations planning product development
Baseline Increment Definition And Requirements Document (IDRD) for Increment 6 Plan: November 1999 Actual:	Baselining the ISS increment in the Increment Definition and Requirements Document Officially initiates increment specific Product and training Development. This typically occurs at 18 months in advance of Increment operations. The IDRD is baselined after Multilateral Increment Training Plan is baselined and a detailed ISS crew training plan is developed

Conduct Increment Operations Review for Increment 2 Plan: Dec 1999 Actual:	Formal program review of integrated operations planning product development
Conduct Increment Operations Review for Increment 3 Plan: March 2000 Actual:	Formal program review of integrated operations planning product development

ACCOMPLISHMENTS AND PLANS

FY 1998

Space Station Control Center (SSCC) activities included completion of the Moscow support room in preparation for the launch of the FGB in early FY 1999. The Houston support room installation was also completed. Interface testing between the Mission Control Center - Houston (MCC-H) and the Mission Control Center-Moscow (MCC-M) began in late FY 1998, and flight 2A end-to-end testing with KSC was completed successfully in early FY 1999.

Space Station Training Facility (SSTF) integration and testing was completed in the fourth quarter of FY 1998 in preparation for flight 2A. The training facility is scheduled to be ready for training for 2A late in the last quarter of FY 1998. Generic training for 2A has been completed. Flight-specific training for 2A also was completed in FY 1998 in preparation for an early FY 1999 launch. Launch processing activities have occurred at the Space Station Processing Facility (SSPF) to support the Integrated Electronic Assembly (IEA) final assembly at the launch site. Delivery and launch site processing of the ISS Z1 truss, long spacer, IEA and MPLM were supported. The Test Checkout and Monitoring System (TCMS) version 2.1, which provides full application software development and end-to-end test capability for flight 6A, was delivered. Version 2.2, which provides Payload Operation Integration Center interfaces and simulation capability to support flight UF-1, was also delivered. The Operations and Checkout Building altitude chamber reactivation was started with an initial design completed and refurbishment activities underway and on schedule. The chamber will be used to vacuum test future ISS elements at the launch site. Initial implementation planning, test objective development, test configuration layout and procedure development began in support of the Multi-Element Integration Test (MEIT). The MEIT will verify the electrical interfaces of Space Station elements. Successful implementation of this test is critical to ensure on orbit performance of the assembled Space Station. Initial set up for this test began late in the fourth quarter of FY 1998.

Operations planning and cargo integration activities include the development and implementation of an Integrated Stowage Plan for pressurized cargo. The process for integrated on-orbit stowage analysis planning was implemented and initiated with Node (flight

2A) stowage rack accommodations planning as well as planning for future missions. Two Zero-G stowage racks were procured, installed into Node 1, and launched on flight 2A in December 1998.

In the logistics and maintenance area, Provisioning Item Orders (PIO's) were issued to begin the initial implementation for the spares hardware build. The Assembly Critical Failures Investigative Team was formed to develop a plan for maintaining critical systems during early assembly. The team identified spares and workaround hardware requirements needed to prevent stoppage in the assembly sequence. The major areas identified were the need for an external spares warehouse, the development of an Early Ammonia Servicer (EAS), and the use of various jumpers as workaround hardware. Assembly critical spares were manifested for flights through 7A.

Sustaining engineering work accomplished in 1998 included the definition, development and implementation of program processes for sustaining engineering. Those processes include those for Government Furnished Equipment (GFE), and Boeing prime and international partners/participants interactions (day-to-day programmatic as well as real-time operations for engineering support). Definition of requirements for and completion of the real-time facilities (mission evaluation room (MER) and engineering support rooms (ESR's) took place. Sustaining engineering support plans for MSFC, JSC and GRC were developed. Design knowledge capture was implemented at all four Boeing sites and a critical skill retention process was initiated at Boeing. Assembly Power Converter Unit (APCU) real-time operations on STS-91 were supported. A generic template schedule and a master-phasing schedule for sustaining engineering products were developed, and a 2A flight-specific schedule for sustaining engineering was baselined. An executable code patch for the Node Control System (NCS) flight software was demonstrated, and a software maintenance consolidation plan for implementation in downstream years was completed. Numerous simulations with the flight control team were also supported.

FY 1999

The Mission Control Center was ready to support flight 2A in the first quarter of FY 1999. In late FY 1999 the Mission Control Center development will be complete. Critical FY 1999 activities in the SSTF include the delivery of training software for flights 2A.1, 2A.2, 3A, 4A, 5A, and 5A.1. Launch site processing work will continue to support launch site testing and launch of ISS flights 2A through 2A.2 and conduct MEIT. Planning and processing support for ISS 7A to UF-1 will be provided and launch site ground support equipment in support of resupply/return flight processing will be delivered. For operations planning and cargo integration, MPLM (flight 5A.1) and airlock (flight 7A) stowage accommodations will be processed and on-orbit stowage planning for flights 2A through 5A will be completed. Nine Zero-G stowage racks will be procured and installed into the Lab (flight 5A).

FY 1999 activities in logistics and maintenance include the identification and issuance of additional PIOs for spares hardware and repair parts. The Super Guppy aircraft will transport the US Lab, S0 structural test article and flight element, airlock, and US Lab structural test article elements to various locations. Manifesting of assembly critical spares for flights beyond 7A will occur this year.

Sustaining engineering planning for 1999 includes providing engineering and technical support required to maintain the hardware post-DD250 for flights 2A - 7A. Real-time engineering support will be provided to the following missions/stages and supporting Progress launches: 1A/R, 2A, 1R, 2A.1, and 2A.2. A remote real-time data access capability for in-home and office use will be implemented. Sustaining engineering products for flights 2A - 10A will be produced. Agreements with MSFC, JSC and GRC on sustaining engineering support and required products and schedule as well as the basic sustaining engineering schedule and baseline schedules for flights 3A - UF-3 will continue to be refined. Bilateral agreements on sustaining engineering with Agencia Spatiale Italiano (ASI), RSA, and CSA will be baselined.

FY 2000

Space Station Control Center training software loads will be delivered for flights 6A, 7A, 7A.1, 8A, UF-1, and UF-2. Standalone Payload Training Capability (PTC) will be ready for flight UF-1 and the integrated PTC will be ready for flight UF-2. Launch site processing activities continue in support of launch site testing and launch of ISS flights 3A through 7A.1. MEIT 2 will also be conducted in FY 2000. Planning and processing support will be provided for ISS flights 9A.1 through 13A, and launch site ground support equipment will be delivered in support of re-supply/return flight processing. Operations planning and cargo integration work will include the processing of stowage accommodations and on-orbit stowage. In FY 2000 the program will continue to identify and issue additional PIOs for spares hardware and repair parts. Transportation activities will continue utilizing the Super Guppy for oversize element transportation, and the project will continue to manifest assembly critical spares.

Sustaining engineering activities for FY 2000 includes providing additional engineering and technical support required to maintain the hardware post-DD250 for flights 8A - 11A. Real-time engineering support will be provided to the following missions/stages and supporting Progress launches: flights 3A, 4A, 5A, 5A.1, 6A, 7A, 4R, and 7A.1. Sustaining engineering products for flights 6A through UF5 will be produced. Agreements with MSFC, JSC and GRC on required products and schedule, as well as baseline schedules for flights UF4 through 16A, will continue to be defined. Bilateral agreements on sustaining engineering with ESA and NASDA will be developed.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE STATION RESEARCH

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Research Projects	113,100	194,500	256,200
Utilization Support	80,500	140,000	138,200
Mir Support (including Mir Research)	32,700	2,000	--
Total	226,300	336,500	394,400

PROGRAM GOALS

NASA will utilize the ISS as an interactive laboratory in space to advance scientific, exploration, engineering and commercial activities. As a microgravity laboratory, the ISS will be used to advance fundamental scientific knowledge, foster new scientific discoveries for the benefit of the U. S., and accelerate the rate at which it develops beneficial applications derived from long-term, space-based research. The ISS will be the world's premier facility for studying the role of gravity on biological, physical and chemical systems. The program will deliver the capability to perform unique, long-duration, space-based research in cell and developmental biology, plant biology, human physiology, biotechnology, fluid physics, combustion science, materials science and fundamental physics. ISS also provides a unique platform for making observations of the Earth's surface and atmosphere, the sun, and other astronomical objects, as well as the space environment and its effects on new spacecraft technologies.

As NASA moves into the Space Station era, there will be a major transition from the current short-term on-orbit experimentation program to the long-term research efforts made possible by the capabilities of the ISS. The core of the Space Station research program will be eight major research facilities: the Gravitational Biology Facility, the Centrifuge Facility, the Human Research Facility, the Materials Science Research Facility (formerly known as the Space Station Furnace Facility), the Biotechnology Facility (which includes Protein Crystal Growth activities), the Fluids and Combustion Facility, the Window Observational Research Facility, and the Low Temperature Microgravity Physics Facility. In addition to the eight major facilities, NASA will develop common-use Laboratory Support Equipment and the Expedite the Processing of Experiments to Space Station (EXPRESS) racks and pallets for the Station.

STRATEGY FOR ACHIEVING GOALS

In 1996 NASA consolidated the management of Space Station research and technology, science utilization, and payload development with the Space Station development and operations program in order to enhance the integrated management of the total content of the ISS budget. The Space Station program manager is now responsible for the cost, schedule and technical performance of the total program. The Office of Life and Microgravity Sciences and Applications (OLMSA), Office of Earth Science, and Office of Space Science remain responsible for establishing the research requirements consistent with the overall Space Station objectives, and funding the principle investigators. The budget reflects this consolidation by funding research capability development within the Space Station account. The research and technology elements of the program, and the Station-related Space Product Development activities are included in the Space Station research budget. A plan for transition of utilization responsibilities back to the research offices once payload facilities are operational will be prepared later this year.

The rephased Assembly Sequence, including the utilization flights, has impacted the planned research program. While still emphasizing early research capabilities, major payload facilities have been delayed on average about eight months. The delivery schedule for research facilities will continue to closely track the buildup of ISS accommodations, in order to ensure the research program ramps up as soon as capability becomes available. The research program will continue to be aligned with the availability of on-orbit resources, including crew time, power and upmass capabilities.

Two research transition flights were added to the Shuttle manifest in FY 1999 and early FY 2001 in order to mitigate research opportunity gaps resulting from the delays in the ISS assembly and utilization schedules. For the FY 2001 mission, the ISS research program will fund an estimated $11.1 million in FY 1999 for payload engineering and integration activities, some experiment unique hardware, and a portion of the carrier cost requirement. The remaining carrier costs and grants and contract costs for the principle investigators will be funded by OLMSA. The FY 2000 requirements are being reviewed in order to fund an appropriate share of the remaining mission costs.

During the early assembly period, the EXPRESS rack program will continue to provide valuable flight opportunities for middeck locker scale experimentation and product development in the areas of biotechnology, biomedical sciences, fluid dynamics and combustion research. Despite delays to the utilization flight plan, we have effectively doubled U.S. research crew time and stowage through our recent negotiations with Russia. The new crew time-stowage balance will position the U.S. for greater experiment productivity from the beginning of the research program. As a direct result, the research program will be significantly enriched because it will allow a greater number of experiments to proceed for longer periods and at increased frequency, thus obtaining many more processed samples and empirical data. Additionally, the ISS program will take advantage of the new logistics flights capabilities of the rephased assembly sequence and will maintain early outfitting by adding the Human Research Facility and two EXPRESS racks on assembly flights 5A.1 and 6A.

Significant progress continues to be made in the establishment of international participation in the provision of U.S. research facilities. The Centrifuge, Centrifuge Accommodation Module, and Life Sciences Glovebox were included in a September 1997 Agreement in Principle with the National Space Development Agency of Japan (NASDA) as partial offset for the Shuttle launch of the JEM. The cryogenic freezer racks and the Minus-Eighty Degree Laboratory Freezer (MELFI) for ISS will be provided by the European Space Agency (ESA) under a March 1997 Memorandum of Understanding. The Brazilian Space Agency (AEB), as a participant in the NASA program, will provide the Technology Experiment Facility, Window Observational Research Facility Block 2, and the EXPRESS Pallet, under an Implementing Arrangement between the U.S. and Brazilian governments.

The Research program is aligned in the following components: Research Projects (including Advanced Human Support Technology, Biomedical Research and Countermeasures, Gravitational Biology and Ecology, Microgravity Research, Space Products Development, Earth Observation Systems, and Engineering Technology), Utilization Support, and Mir Support.

Research Projects

The primary objective of Advanced Human Support Technology (AHST) is the definition, development and testing of advanced technology hardware and processes in support of humans-in-space engineering and life support, and extra-vehicular activity. Specific areas of potential research which have been identified include closed loop life support systems (CO2 reduction and O2 generation), biological water recovery, advanced telemetric biosensors, and wearable computers.

The mission of the AHST research and technology development facility is to identify, develop, and perform flight demonstration, testing, and validation of selected advanced technologies consistent with Space and Life Sciences and the NASA Strategic Plan. These flight experiments will demonstrate miniaturization, low power consumption, high reliability, ease of use, and cost effectiveness for technologies which play a role in life support, environmental monitoring and control, biomedical research and countermeasures, crew health care, and extravehicular activities. The AHST rack will provide a means for taking advanced technologies, which may originate within or outside NASA, to levels of maturity beyond what could be accomplished through ground testing alone. This effort will enable rapid accommodation of advanced technologies into operational systems on the ISS. The initial AHST facility payload on the Station is planned as a single modified EXPRESS rack which will support rotation of subrack payload investigations with a typical duration of 90-180 days.

Biomedical research facilities and activities include the following: the Human Research Facility (HRF), the Crew Health Care Subsystem (CHeCS) and the associated payload development. The HRF provides an on-orbit laboratory that will enable life science researchers to study and evaluate the physiological, behavioral, and chemical changes in human beings induced by space flight. Research performed with the HRF will provide data relevant to long adaptation to the space flight environment. Many capabilities developed for the HRF have Earth-based application. HRF hardware will enable the standardized, systematic collection of data from the Space Station's crewmembers, which the medical and research community will require in order to assure crew health. Once verified on-orbit, the HRF will also be used to conduct basic and applied human research and technology experiments.

In addition to the biomedical research that will be conducted using the HRF, NASA's biomedical activities aboard the ISS will include the suite of hardware necessary to protect crew health. The CHeCS will support medical care requirements for the ISS crew following deployment of the U.S. Laboratory module. CHeCS hardware will provide inflight capabilities for ambulatory and emergency medical care. It will support monitoring of medically necessary environmental parameters, along with capabilities for counteracting the adverse physiological effects of long-duration space flight. Hardware commonality between CHeCS and the HRF is being evaluated, with the synergy between the two programs resulting in maximum research efficiency and cost savings.

The Gravitational Biology and Ecology facilities and activities include the Gravitational Biology Facility (GBF), the Centrifuge Facility, and associated payload development activities, comprise a complete on-orbit laboratory for biological research. The GBF will design, develop, and conduct the on-orbit verification of Space Station research equipment to support the growth and development of a variety of biological specimens, including animal and plant cells and tissues, embryos, fresh and salt water aquatic organisms, insects, higher plants, and rodents. The GBF will support specimen sampling and storage as well as limited analysis activities. The GBF modular design will accommodate the incremental development of experiment capabilities in a manner consistent with evolving ground and flight science needs of the research community.

The Centrifuge Facility includes two habitat holding systems, a centrifuge rotor, life sciences glovebox, and two service system racks. Under the NASA-NASDA Agreement in Principle, NASDA will provide the centrifuge rotor, life sciences glovebox and the Centrifuge Accommodation Module. A formal implementing arrangement to cover Japans contribution is expected to be concluded in early 1999.

Microgravity Research activities include development of the Fluids and Combustion Facility, Material Science Research Facility, Biotechnology Facility, Low-Temperature Microgravity Physics Facility, and payload development.

The Fluids and Combustion Facility (FCF) supports research on interfacial phenomena, colloidal systems, multiphase flow and heat transfer, solid-fluid interface dynamics, and condensed matter physics, and definition of the mechanisms involved in various combustion processes in the absence of strong buoyant flows. The FCF is a three-rack payload. The Fluids Integration Rack is designed to accommodate several multi-purpose experiment modules that are individually configured with facility-provided and experiment-specific hardware to support each fluids experiment. The Combustion Module houses a combustion chamber that is equipped with ports to allow an array of modular diagnostic systems to view the experiment. The facility core rack will provide common support systems for both the combustion and the fluid payload racks; however, the combustion and fluid racks are being designed to operate as standalone hardware during the Station assembly period with more constrained capability.

The development of the Space Station Furnace Facility (SSFF) was reassessed in FY 1997 and resulted in reduced FY 1999 funding requirements. This project has been renamed the Materials Science Research Facility (MSRF) and is being restructured to provide the maximum opportunity for material research early in the Space Station assembly sequence, with the ultimate goal of a mature 3-rack facility by the end of assembly. This project will be used to study underlying principles necessary to predict the relationships of synthesis and processing of materials to their resulting structures and properties. Cooperative efforts are underway with the international science community that will assist in the development of some discipline-specific furnace modules for use by the U.S. science community, thus leveraging the hardware development investments undertaken by NASA.

The Biotechnology Facility (BTF) supports research in the areas of protein crystal growth and cell tissue cultures which include studies on the maintenance and response of mammalian tissue cultures in a microgravity environment. The facility will provide a support structure as well as integration capabilities for individual biotechnology experiment modules. Its modular design will provide the flexibility to accommodate a wide range of experiments in cell culturing and protein crystallization. The facility will accommodate changes in experimental modules and analytical equipment in response to changes in science priorities or technological advances. The BTF will support a large group of academic, industrial and government scientists.

The objective of the Low Temperature Microgravity Physics Facility (LTMPF) is to investigate the fundamental behavior of condensed matter without the complications introduced by gravity. Primary LTMPF research will study the universal properties of matter at phase transitions and the dynamics of quantum fluids. The LTMPF will be a remotely operated payload package attached to the Japanese Exposed Facility of the Station and is expected to improve measurements by a factor of 100 over similar terrestrial tests. This attached payload facility will support two independent research instruments simultaneously (at a temperature between 0 and 4 degrees Kelvin) and provide 6 to 8 months of microgravity operation between reservicing and hardware changeout.

NASA's commercial research programs for ISS will take advantage of the new opportunities for space flight operations provided by the ISS, and a distinctly new operating environment. Among other activities, the commercial research programs for the ISS will concentrate on commercial protein crystal growth and plant growth research. The commercial protein crystal growth activities for ISS are underway at the Center for Macromolecular Crystallography, and plant growth research at the Wisconsin Center for Space Automation and Robotics, the Center for Bioserve Space Technologies, and their industrial affiliates. NASA released the draft Commercial Development Plan for the ISS in the first quarter of FY 1999. The plan will be refined and initial steps will begin towards implementation later in the year.

Stratospheric Gas and Aerosol Experiment (SAGE III) will measure chemical properties of the Earth's atmosphere between troposphere and the mesosphere. A key aspect of this research will investigate effects of aerosols on ozone depletion in the atmosphere. SAGE III is a payload attached to the outside of the Station and will be mounted on an ESA-provided precision-pointing platform.

The Window Observational Research Facility (WORF) will be located in the U.S. Laboratory Module at the zenith- (Earth) pointing window location. The WORF, which includes a high-quality window and a special rack structure to support optical equipment attachment, will provide a crew workstation for research-quality Earth observations of rare and transitory surface and atmospheric phenomena. The first version, the Block 1 WORF, is being developed as a research testbed for early utilization during the Station assembly sequence. A more mature Block 2 version is planned to be provided by the Brazilian Space Agency as a subsequent upgrade.

The Engineering Research Technology (ERT) program will maximize the use of the ISS as a unique on-orbit laboratory, thereby fostering the partnerships with other U.S. Government, industrial and academic communities. The ERT program will identify and define innovative technology concepts, develop these concepts into flight experiments, and perform the necessary laboratory-scale investigations on-board the ISS to validate the physical characteristics advanced by these concepts. The program promotes the fast track implementation of these experiments. At the same time, the ERT program will obtain proposals for the facilities which can provide the necessary support for one or more experiments to operate without duplication of functions.

The scheduled launch of the various science capabilities mentioned above has been affected by recent implementation of a new assembly sequence and further budget reductions. The new schedule for deployment of these facilities is in work.

Utilization Support

Utilization Support provides the necessary capabilities to integrate and operate payloads of commercial, academic and government researchers on the ISS. These capabilities provide the facilities, systems and personnel to support the ISS user community in efficient and responsive user/payload operations. Support is provided for flight and ground capabilities to ensure efficient and complete end-to-end payload operations. Telescience operations are supported to maintain the highest flexibility for both the user community and NASA at the lowest cost. NASA and International Partner payload operations are integrated to ensure compatible use of ISS resources and to resolve payload requirement conflicts.

Utilization Support provides pre-flight payload engineering integration, verification and checkout support, payload operations integration, payload training, mission planning, real-time operations support, data processing and distribution and launch site support. Services begin with initial definition of the payload for flight and continue throughout onboard ISS operation and return of experiment's data and equipment to the user. Services include documentation of interfaces and verification requirements, training of ground and flight teams, and development and execution of mission plans to meet the needs of the user community. Mission execution activities have been streamlined to allow greater payload operational flexibility.

On the ground, the Payload Operations Integration Center (POIC)/United States Operations Center (USOC), Payload Data Services System (PDSS), and the Payload Planning System (PSS) provide the user community with the tools and resources to access ISS flight payload services and conduct operations from their home laboratories. For those users who do not have access to command and telemetry processing capability at their home location, the USOC provides accommodations for them to conduct their ground-based operations support. Development cost of these systems has been reduced by utilizing generic architecture which supports multiple programs including Space Shuttle, Spacelab, and the Chandra X-Ray Observatory (CXO, formerly known as AXAF).

Utilization Support also assists payload developers through the provision of payload checkout and verification tools needed for development and verification of their payloads. Among the systems provided are the Payload Rack Checkout Unit (PRCU), and the Suitcase Test Environment for Payloads (STEP). A Payload Data Library (PDL) will provide a single electronic interface for payload developers to provide the requirements and data necessary for the ISS to integrate and operate their experiments.

NASA's Utilization Support will also provide the necessary integration across all International Partner payload planning and operations to ensure efficient, compatible use of Space Station payload resources.

In addition to the major facility-class payloads, NASA plans to fly smaller, less complex payloads on the ISS which will typically have more focused research objectives and shorter development time cycles and will be easily adapted to a variety of users. An EXPRESS Rack concept has been adopted to drastically shorten user pre-flight payload preparation activities. The EXPRESS rack will enable a simple, streamlined analytical and physical integration process for small payloads by providing standard hardware and software interfaces. The project flight and ground systems were successfully demonstrated on a precursor flight of an EXPRESS rack in FY 1997 on the MSL-1 Spacelab mission. The EXPRESS pallet project provides small attached payloads with a similar streamlined process and hardware and software interfaces. The Brazilian Space Agency is responsible for developing the EXPRESS pallets for NASA.

Laboratory Support Equipment (LSE) is also under development for the Space Station in order to support Life and Microgravity Sciences and other experiments. This equipment includes a digital thermometer, video camera, passive dosimeter, specimen labeling tools, microscopes, small mass measurement device, pH meter, and an incubator. A cryogenic transport freezer and low-temperature onboard freezers are also being developed to support Station research activities.

Mir Support (including Mir Research)

The Mir program provided for early research opportunities during Phase 1 by conducting long-duration science aboard the Russian Mir space station, as well as shorter duration science investigations on the Space Shuttle rendezvous missions to Mir. Nine Space Shuttle missions to Mir have been completed. The primary objectives of these flights were to rendezvous and dock with the Mir; perform on-orbit, joint U.S./Russian science and research; perform on-orbit joint operations, serve as a platform for future ISS operations; resupply Mir logistics; and rotate the American astronauts on-board Mir. The program was completed with the final flight in May 1998.

SCHEDULE & OUTPUTS

Research Projects

Centrifuge Rotor and Life Sciences Glovebox - Systems Requirements Review (SRR) Plan: 3rd Qtr FY 1998 Actual: 4th Qtr FY 1998	Agreement in Principle signed September 10, 1997. NASDA issued development contracts in early 1998. A System Requirements Review (SRR) and draft Joint Implementation Plan were completed in FY 1998. Experiment Requirements Reviews were completed recently on the Life Sciences Glovebox and Centrifuge Rotor. Preliminary Design Review (PDR) will be held in mid-1999.
FCF Combustion System Preliminary Design Review (PDR) Plan: Under review Revised: 3rd Qtr FY 2000	The FCF program was restructured and a Hardware Concept Review was conducted in FY 1998. A PDR is planned for FY 2000. This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage.
MSRF Rack 1 Critical Design Review (CDR) Plan: Under review Revised: 4th Qtr FY 1999	This SSFF project was renamed Materials Science Research Facility and restructured and re-baselined in FY 1998. A requirements assessment review was accomplished during the 3rd Qtr FY 1998. The CDR for the first rack will be held late in the 4th Qtr of FY 1999.
CHeCS Complete manufacture and assembly of qualification hardware Plan: 3rd Qtr FY 1997 Revised: 2nd Qtr FY 1999	CHeCS provides crew health care system hardware included in the health maintenance system, and the countermeasure system required to ensure crew health and safety. While the CHeCS rack is not qualified at a system level, the date listed represents the qualification of the last item integrated into the rack.
HRF System CDR, Rack 1 Plan: 1st Qtr FY 1997	This review verifies the suitability of the design in meeting the specified requirements and establishes its "build-to" project baseline. 90% of flight drawings should be complete at this

Revised: 1st Qtr FY 1999	stage.
GBF CDR Rack 1 Plan: 3rd Qtr FY 1997 Actual: 3rd Qtr FY 1998	A CDR level review was held for the Habitat Holding Racks. This review verified the suitability of the design in meeting the specified requirements and established its "build-to" project baseline.
Biotechnology Facility PDR Plan: 3rd Qtr FY 2000	This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage.
MSRF Rack 2 Critical Design Review (CDR) Plan: 4th Qtr FY 2000	This review verifies the suitability of the design in meeting the specified requirements and establishes its "build-to" project baseline. 90% of flight drawings should be complete at this stage.
Low Temperature Physics Facility CDR Plan: 4th Qtr FY 2000	This review verifies the suitability of the design in meeting the specified requirements and establishes its "build-to" project baseline. 90% of flight drawings should be complete at this stage.

Utilization Support

EXPRESS Rack Final Testing and Reviews Plan: 3rd Qtr FY 1999	Structural buildup, final documentation, safety reviews and testing are in work. Subrack integration and final acceptance are scheduled in 3rd Qtr FY 1999 for launch on flight 6A.
Complete POIC/USOC and facilities outfitting Plan: 1st Qtr FY 1998 Revised: 4th Qtr FY 1999	Includes workstation upgrades in Payload Operations Integration Center (POIC) and U.S. Operations Center (USOC) at MSFC. Complete communications outfitting 3rd Qtr FY1998, remainder of facilities outfitting 4th Qtr FY 1999 to support UF-1 launch preparations.
EXPRESS Pallet PDR Plan: 2nd Qtr FY 1998 Revised: 3rd Qtr FY 1999	This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage.
Complete PP2 Baseline IDRD Plan: 1st Qtr FY 1998 Actual : 4th Qtr FY 1998	The Interface Definition and Requirements Document (IDRD) describes the on-orbit resources (volume, power, data, etc.) allocated to all payloads. The IDRD for Planning Period 2 (including flight 5A) has been given priority and was baselined in FY 1998.
WORF Block 1 PDR Actual: 4th Qtr FY 1998	This review establishes the "design-to" baseline and ensures that it meets the project baseline requirements. 10% of the flight drawing should be complete at this stage.

WORF Block 1 CDR Plan: 4th Qtr FY 1999	This review verifies the suitability of the design in meeting the specified requirements and its "build-to" project baseline. 90% of flight drawings should be complete at this stage.
Payload Crew Training Plan: 2nd Qtr FY1999 Revised: 1st Qtr FY 1999	Training will begin for the first crew operating payloads on 5A.1.
PDSS Initial Operations Capability Plan: 2nd Qtr FY 1999	The capability to process Ku-band telemetry data for the UF-1 and UF-2 missions will be delivered.
Communications Link Activation Plan: 1st Qtr FY 1999 Revised: 2nd Qtr FY 2000	The communication link from the Huntsville Operations Support Center (HOSC) to the Space Station Control Center (SSCC) will be activated to support payload training and operations.
PPS Build 2 Plan: 3rd Qtr FY1999	The Payload Planning System (PPS) capabilities required to support the UF-1 and UF-2 missions will be delivered.

Mir Support (including Mir Research)

NASA/Mir 5, 6,7 Launches Plan: 2nd Qtr FY 1997 (Mir-5) Actual: January 1997 Plan: 3rd Qtr FY 1997 (Mir-6) Actual: May 1997 Plan: 4th Qtr FY 1997 (Mir-7) Actual: September 1997	Spacehab mission management and integration functions for module flights 5, 6, 7, 8 and 9 were performed by Spacehab, Incorporated. Life sciences research on Biorack investigated cellular functions and developmental processes in plant and animal tissues. Microgravity objectives focused on reducing scientific risk and enhancing long duration experiment performance and science utilization in preparation for ISS. A multi-disciplined joint U.S./RSA research program was conducted on a continuous basis on board Mir during this period, and NASA had a U.S. astronaut on board Mir throughout the period.
NASA/Mir-8 Launch Plan: 2nd Qtr FY 1998 Actual: 2nd Qtr FY 1998	Same as above.
NASA/Mir-9 Launch Plan: 3rd Qtr FY 1998 Actual: 3rd Qtr FY 1998	Same as above. Completion of this mission marked the end of Phase 1 of the ISS program.

ACCOMPLISHMENTS AND PLANS

Research Projects - FY 1998

Development of International Space Station facility-class payloads made significant progress during FY 1998.

Structural buildup of the first two EXPRESS Racks, final documentation, safety reviews and testing are in work. The first two racks have begun subrack integration and are scheduled to be accepted in the 3rd Qtr FY 1999 for launch on flight 6A. Ten EXPRESS Suitcase Simulators have been completed.

A Systems Requirements Review (SRR) and draft Joint Implementation Plan for the Centrifuge Accommodations Module, Centrifuge Rotor and Life Sciences Glovebox were accomplished. Buildup of the qualification hardware and the Critical Design Review (CDR) occurred for the Gravitational Biology Facility Habitat Holding Rack. The Cell Culture Unit accomplished a Preliminary Design Review (PDR). The Life Sciences Glovebox completed an Experiment Requirements Review (ERR).

The PDR for Rack 1 of the Human Research Facility was held, and the certifications for the Launch Integration Facility and the Ground Development Facility at JSC were completed. The Flight Prototype Rack was received, and testing of the rack began. Fabrication of the Ultrasound and the Gas Analysis System for Metabolic Analysis Physiology (GASMAP) continued with delivery of flight articles planned in early FY 1999.

The Fluids and Combustion Facility completed a restructure and hardware concept review. The Space Station Furnace Facility was renamed the Materials Science Research Facility and rebaselined during FY 1998. Rack #1 completed a PRR. A CDR was accomplished for the Microgravity Science Glovebox. The Phase I Biotechnology Facility completed operations on the Mir Space Station. The Phase II ISS Biotechnology EXPRESS Subrack configuration continued preparation for flight on UF2.

The Stratospheric Gas and Aerosol Experiment (SAGE III) completed a Systems Acceptance Review (SAR) and Phase 1 Safety Review during 1998. Fabrication of science instrument parts was completed. Flight qualification testing of new detector software code was also completed.

The commercial research program continued to concentrate on commercial protein crystal growth, with the intent to increase the number of samples that can be processed in a given volume, monitor and control growth conditions, and develop a new generation of thermal enclosures for crystal growth.

A communications outage recorder was incorporated into the ISS baseline. A medium rate COR will be launched on 5A.1 utilizing commercial off-the-shelf hardware. A high rate COR will replace the medium rate COR by UF3.

Increment training for the first payloads crews on 5A.1 and 6A began in late 1998. Payloads support to the Multi-element Integration Testing program was initiated with the Human Research Facility Flight Prototype Rack.

A Memorandum of Agreement (MOA) was developed during FY 1997 between the JSC Space and Life Sciences Directorate and the ISS Payloads Office which will permit the sharing of hardware and research between the HRF and the Crew Health Care Subsystem (CHeCS). CHeCS will provide for medical care for the ISS crew following deployment of the U.S. Laboratory module, and will provide operational exercise, countermeasures and environmental monitoring aboard the ISS. As a result of this MOA, which was signed in FY 1998, hardware commonality between CHeCS and the HRF was evaluated, and the efficiency and cost savings of the two programs was maximized.

Research Projects - FY 1999

Development of ISS research facilities and experiment-unique hardware will continue toward launch on 5A.1 and 6A. The Microgravity Science Glovebox training hardware will be shipped to JSC to support the launch on UF-1. The Fluids and Combustion Facility Combustion Integrated Rack will complete a PDR and a Phase 1 Safety Review. The Microgravity Science Research Facility Rack #1 will complete a CDR and Rack #2 will complete a PRR. The Biotechnology Facility will accomplish a Requirements Definition Review (RDR). The Low Temperature Microgravity Physics Facility will finalize the design concept in FY 1999.

The Centrifuge Facility and Life Sciences Glovebox will conduct PDRs in FY 1999. The Gravitational Biology Facility Cell Culture Unit will conduct a CDR, the Insect Container Unit will conduct a PDR, and the Plant Research Unit will conduct a PRR.

Rack 1 of the Human Research Facility will complete a CDR and be delivered to KSC to be flown on flight 5A.1. Rack 2 of the Human Research Facility has been accelerated to fly on 12A.1. Flight units of the following hardware will be delivered: ultrasound, GASMAP, computer workstation, foot/ground interface, activity monitor, continuous blood pressure device, range of motion (ROM) suit, common battery, hand grip dynamometer, and the lower-body negative pressure device. The HRF Flight Prototype Rack (FPR) will be included in the MEIT at KSC in mid-FY 1999. Objectives will be to verify the ISS interfaces (electrical, thermal, communications, data, etc.), verify ISS payload test tools, and to verify HRF integration tools (Launch Integration Facility, Flight Prototype Rack, and Suitcase Test Environment for Payloads). In addition, MEIT will identify potential design problems or incompatibilities between the HRF rack and the U.S. Lab to be resolved prior to launch, and will validate tests and test procedures that will be used in the integration, verification, and flight certification of the HRF Flight Rack for 5A.1.

The Stratospheric Gas and Aerosol Experiment (SAGE III) flight instrument is scheduled for delivery to NASA for launch on UF4. It will complete an instrument CDR and Hexapod CDR during 1999. In addition, flight instruments assembly and subsystem testing will be completed in FY 1999. As part of the ESA Early Utilization Agreement, ESA will provide a hexapod pointing platform for SAGE III which will provide the 1-degree of pointing accuracy required by the payload.

The Engineering Research Technology program will conduct PDRs for the Attitude Control and Energy Stowage Experiment (ACESE) and the Optical Communications Demonstration (OCD) projects in FY 1999. ACESE system and software architecture will be finalized in FY 1999. Interim design reviews will be held for three other projects, Flexible Control Structures; Photovoltaic Engineering Testbed; and the Micron Accuracy Deployment Experiment.

Research Projects - FY 2000

In FY 2000, NASDA will complete the Life Science Glovebox and Centrifuge Facility CDRs. The Human Research Facility Rack #1 will be on-orbit and Rack #2 will be readied for launch on 12A.1.

The Microgravity Sciences Glovebox and the Minus Eighty-Degree Laboratory Freezer (MELFI) will be readied for launch on UF-1

The Fluids and Combustion project will accomplish the Shared Accommodation Rack, Fluids Integrated Rack and Integrated Facility PDRs and the Combustion Integrated Rack CDR. Outfitting of the Combustion Integrated Rack will be completed and system and subsystem testing accomplished. The Microgravity Science Research Facility Rack #2 will complete its CDR. The ISS Biotechnology Facility will complete a PDR, the EXPRESS Rack level biotechnology and fluid physics payloads will be on-orbit, and the Low Temperature Microgravity Physics Facility will complete a CDR.

Utilization Support - FY 1998

In FY 1997, a decision was made to defer full payload operations support capability to the UF-3 time frame consistent with Space Station funding priorities for FY 1998. Requirements for initial operations capability (IOC) in the POIC, PDSS, PPS, and Payload Training Center (PTC) have been changed to support flights 5A.1 and 6A for the first use of payloads on the ISS based on the current assembly sequence. Payload training plans and simulator requirements were defined for the 5A.1 and 6A payloads, and the first two STEP units were delivered to payload developers.

The Payload Data Library (PDL) initial data set development was completed in FY 1998. The Payload Rack Checkout Unit (PRCU) development was delayed due to late software delivery from the Space Station vehicle. The first PRCU was delivered in FY 1998. Payload integration for 5A.1 and 6A payloads has begun, including development of preliminary ICDs and Payload Integration Agreements (PIAs) for payloads.

In FY 1998, development of the initial operations capability to support 5A.1 and 6Aby the POIC, PDSS, PDL, PTC and PPS continued. The support communications services for the POIC/PDSS were put in place, enabling connectivity between the POIC and remote payload investigators. PPS Build 1 test and integration were completed and flight product development for payload complement began. The payload unique ICDs and verification plans were completed and the PIAs were baselined.

Fabrication and testing of the first EXPRESS rack to fly on the ISS began in FY 1998. The first EXPRESS racks are planned for launch on flights 6A and 7A.1. A total of 10 "suitcase" EXPRESS rack interface simulators are being fabricated for use by EXPRESS payload developers. All ten simulator units were delivered to payload development sites in FY 1998.

The Window Observational Research Facility (WORF) design was upgraded to incorporate the ISPR rack, and operational responsibility was transferred to MSFC to leverage off the EXPRESS Rack experience and hardware. WORF payload services were upgraded to include power, data and thermal control. A SRR and PDR were completed.

An implementing arrangement was signed in October 1998 to transfer development responsibility for the EXPRESS Pallet to the Brazilian Space Agency. EXPRESS Pallet engineering integration, payload software verification, and on-orbit operations will remain the responsibility of NASA. A Joint Management Plan for pallet development was completed. A PDR for the pallet is scheduled for FY 1999 for a first flight on UF-3.

Utilization Support - FY 1999

In FY 1999, the Huntsville Operations Support Center (HOSC) will be declared operationally ready to support 5A.1 and 6A payload operations. Many of the flight products will be completed and integrated with the systems operations products. The first payload crew will begin training for the missions and the integrated engineering and operational assessments will be performed for the payload complements. Development will continue on the final operations capabilities of the PDSS, PPS, and PTC to support the UF-3 mission.

During FY 1999, the first four EXPRESS Racks will be readied for delivery to KSC and launch on flights 6A and 7A.1. EXPRESS Rack trainer units are to be completed in the first quarter of FY 1999. These units will be used for procedure development and crew training to support the 6A and subsequent flights. Subsystem hardware integration and verification will be completed by mid 1999. In addition, four EXPRESS Transportation Racks will be delivered to NASA used for transporting EXPRESS payloads to and from EXPRESS racks already on-orbit.

A PDR for the EXPRESS Pallet is scheduled for FY 1999.

An Operational Readiness Review (ORR) for the Telescience Support Center (TSC) will be held for JSC. Crew training in the Ground Development Facility (GDF) will begin for activation of the rack on-orbit and human research experiments to be conducted, followed by start of training in the Hi Fidelity Mock-up.

The Window Observational Research Facility (WORF) will accomplish its CDR and deliver the flight rack to KSC for flight on UF2. Installation of the optical quality window glass in the U.S. Laboratory module is scheduled for the third quarter of FY 1999.

Utilization Support - FY 2000

Four EXPRESS Racks will be on-orbit and conducting operations. Delivery, final testing, and subrack integration for the fifth EXPRESS Rack and the Window Observational Research Facility will be completed for launch on UF-2.

Mir Support – FY 1998

During FY 1998, two Shuttle flights to Mir were flown which included one Spacehab double module in January and one single module in May. American astronauts spent eight months aboard Mir conducting research. The Phase 1 Mir program concluded its flight program in mid-year after nine successful Shuttle flights.

Mir Support - FY 1999

The data analysis and publication of results from the Phase 1 Mir research program will be completed in FY 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE STATION RUSSIAN PROGRAM ASSURANCE

	FY 1998*	FY 1999**	FY 2000
	(Thousands of Dollars)		
Step one	[50,000]		
Step two	[60,000]	248,300	200,000
Total	[110,000]	248,300	200,000

* In FY 1998, Russian Program Assurance (RPA) was funded in the US/Russian Cooperation and Program Assurance budget line item within the Human Space Flight appropriation account. It is displayed within the International Space Station account to reflect the FY 2000 restructured budget.

** The December 22, 1998 operating plan includes $53 million for Russian Program Assurance (RPA) for FY 1999. This budget assumes additional reallocations of $195.3 million from Vehicle to RPA in FY 1999.

PROGRAM GOALS

In FY 1997, the budget line item entitled, U.S./Russian Cooperation and Program Assurance, was established. This budget line item had two parts, U.S./Russian Cooperation (Russian Space Agency contract support) and Russian Program Assurance (RPA). The first part has been completed. The second part, Russian Program Assurance (RPA), was re-established within the Space Station budget line. The RPA budget was established to fund contingency activities and backup capabilities in response to concerns about the impact of the Russian Government's fiscal problems on meeting their ISS commitments. These concerns were heightened by the slippage of the Russian service module (SM) from May 1998 to December 1998, and then to the fourth quarter of FY 1999.

NASA's approach to contingency planning is to incrementally fund only those activities that permit the United States to continue to move forward should the planned contributions of our ISS partners not be delivered as scheduled, rather than to assume the responsibilities of other ISS partners. It is a process based on: 1) identification of risks; 2) development of contingency plans to reduce these risks; 3) establishment of decision milestones and the criteria by which action will be taken; and, 4) implementation of contingencies as necessary. The RPA funding provides contingency activities to address ISS program requirements resulting from delays on the part of Russia in meeting its commitments to the ISS program, allowing the U.S to move forward and build the ISS in spite of Russian shortfalls. These contingency activities are not intended to protect against the loss of Russian contributions. That impact would cause an extended delay to the program, necessitating additional crew return, life support, reboost, and guidance and control capabilities to replace planned Russian contributions, and result in a significantly less robust space station.

BACKGROUND

For several years Russia has experienced significant economic problems. The fiscal shortfalls experienced by the Government of Russia have resulted in the Russian Space Agency (RSA) receiving only a fraction of its approved budget. The shortfalls have resulted in schedule slips of the ISS hardware and operations support that Russia was responsible for funding and providing. To accommodate this shortfall, the U.S. developed a three step contingency plan and initiated specific developments to protect the ISS schedule and capabilities in the event of further Russian delays or shortfalls. In spring 1997, NASA embarked on the initial steps of a contingency plan to provide U.S. capabilities to mitigate the impact of further Russian delays. Step one consisted primarily of the development of an Interim Control Module (ICM), built by the U.S. Naval Research Laboratory for NASA, to provide command, attitude control, and reboost functions in the event the Russian Service Module was not provided. Over the last year we have continued to see further delays on the Russian elements. Therefore, during summer 1998, NASA initiated activities to implement Step two of the contingency plan to provide flexibility for the United States in the event of further Russian delays. Step two consists primarily of building a U.S. propulsion capability, enhancing logistics capabilities, modifying the Shuttle fleet for enhanced Shuttle reboost of ISS, and procurement of Russian goods and services to support Russian schedules for the Service Module and early ISS Progress and Soyuz launches. NASA expects to procure some additional Russian hardware and services in FY 1999 to provide further Russian schedule protection.

STRATEGY USED FOR ACHIEVING STEP ONE GOALS

The U.S./Russian Cooperation and Program Assurance (RPA), as part one Step one, was initiated in May 1997. It provided contingency planning funds to address ISS program requirements resulting from delays on the part of Russia in meeting its commitments to the ISS program. The first step in the contingency plan, which was to protect against a potential further delay in the SM, has been implemented. The ISS program is purchasing an interim control module (ICM) from the U.S. Naval Research Laboratory (NRL) to provide the U.S. with an option for performing attitude control and reboost functions which the Russian service module is to perform. This option could allow continuation of the ISS assembly sequence without the Russian SM. The NRL's ICM is currently being prepared to support a March 2000 launch to back up any shortfall of Progress fuel resupply vehicles. The Program is also maintaining an option to attach it to the back of the Russian-built functional cargo block (FGB), should the Russian Service Module slip considerably beyond its scheduled launch in the fourth quarter of FY 1999.

Step One of NASA's RPA contingency plan had two primary components. First, modifications were done to the Zarya, an element purchased from Russia and owned by the U.S, to enhance the Zarya's propulsion control capabilities and make it refuelable. The Zarya was launched on November 20, 1998. Second, the development of an interim control module (ICM)was initiated. The Zarya modifications and the ICM addition will enable the on-orbit build to continue even without the Russian Service Module, although not as planned due to the loss of the Service Module's habitation resources. This would result in increased risk due to the absence of an ISS-based crew to address real-time problems, which can be expected to arise. It would also result in lost research opportunities, resulting in a significant research gap or the introduction of new Shuttle based research opportunities. Other RPA activities included purchase of docking adapters and SM flight support equipment from RSA, airlock modifications, O^2 compressor for the airlock, and other related ICM tasks. In 1999, RPA funding for Step one will support the completion of assembly, test and checkout of the ICM.

STRATEGY USED FOR ACHIEVING STEP TWO GOALS

During summer 1998, NASA undertook initial efforts in Step two of the contingency plan to provide flexibility for the United States and our international partners in the event of further Russian delays. These efforts included initiation of development of an enhanced Shuttle reboost capability for the ISS. This long-term reboost capability will augment the existing Shuttle reboost capability, and will be obtained by modifying the Shuttle orbiters so that the maximum amount of excess maneuvering propellant can be utilized by the Shuttle to reboost the ISS while docked. Also as part of Step Two, to further reduce U.S. reliance upon Russian contributions, NASA is proceeding with the development of a U.S. propulsion capability which would provide permanent, independent reboost and attitude control. NASA will continue to evaluate options for securing a permanent U.S. propulsion capability into the second quarter of fiscal year 1999, in parallel with performing prestart requirements analysis and long lead procurements for a Boeing proposed propulsion module. A decision is planned in the second quarter of FY 1999 to authorize a new development project to provide a U.S. propulsion capability.

In parallel to the development of independent U.S. capabilities for long-term self-reliance, NASA has maintained a regular dialogue with RSA representatives to fully understand their fiscal situation. The Administration and the Congress responded affirmatively to NASA's September 1998 recommendation to provide the RSA immediate funding to help ensure timely delivery of the critical Russian Service Module and to avoid costly delays in the first launches of ISS hardware. NASA entered into a contract with the Russian Space Agency to secure valuable crew time to conduct U.S.-directed research, and procure critically needed research stowage space. This agreement, funded at $60 million, provided funds that allowed RSA to maintain delivery schedules for the Service Module and other early Russian contributions.

To ensure uninterrupted continuation of ISS assembly, including certainty regarding availability of Russian Progress and Soyuz vehicles--at the same time that development of independent U.S. capabilities is being pursued--NASA's contingency planning envisions the possibility of further negotiation with Russian entities for purchase of appropriate goods and services in the future. Consistent with direction in the FY 1999 VA-HUD-Independent Agencies appropriations bill (P.L. 105-276), NASA is evaluating alternative approaches whereby NASA could contract with Russian entities for goods and services related to the ISS. This report should be completed in the second quarter of FY 1999. Where appropriate, NASA is prepared to competitively bid these requirements. NASA has continued discussions with the RSA regarding the purchase of a Soyuz return vehicle as well as the purchase of Soyuz trainers, increased stowage, and other goods and services. The purchase of a Soyuz is highly desirable because it will enable deployment of six crew to orbit prior to the availability of a U.S. Crew Return Vehicle (CRV). At present NASA can not achieve an increased crew complement on orbit until the U.S. Crew Return Vehicle is completed and operational. NASA is considering a Soyuz purchase in the second quarter of FY 1999.

NASA believes that this approach, working with Russia to assure near-term critical capabilities while developing independent U.S. capabilities over the long-term, provides the best approach to address the impacts from the Russian economic situation. NASA will be prepared to provide some of the logistics requirements that Russia agreed to provide, should RSA experience insufficient funding from their government. This will require Shuttle logistics flights for dry cargo and reboost of the ISS stack, as well as the procurement of logistics carrier support until a permanent U.S. propulsion capability is delivered. The potential use of orbiter vehicle OV-102 to meet some of these logistics requirements requires the installation of a docking module and this is also included in Step 2. The International Space Station Intergovernmental Agreement and the bilateral Memorandum of Understanding between NASA and RSA provide the flexibility to modify Russian participation in the ISS Program through a rebalancing of partner contributions and benefits.

SCHEDULE & OUTPUTS

ICM CDR Plan: December 1997 Actual: December 1997	NRL and ISS program office completed the critical design review (CDR) for the ICM
SM Launch Plan: December 1998 Revised: 4th Qtr FY 1999	The SM will be launched as part of the ISS Revision D Assembly Sequence
FDRD Completed Plan: February 1998 Revised: June 1999	Flight design requirements document (FDRD) baseline established in order to allow Shuttle to begin flight design processes
ICM Cargo Integration Review Plan: April 1998 Revised: October 1999	Review of cargo element with Shuttle Program
ICM Phase III GSR Plan: October 1998 Revised: March 1999	Phase III ground safety review at KSC
ICM Stage Integration Review Plan: November 1998 Revised: January 1999	Stage integration review
ICM Ship to KSC Plan: December 1998 Revised: Fall 1999	Begin launch processing, ground operations at KSC
ICM Launch Readiness Plan: February 1999 Revised: 2nd Qtr FY 2000	Planned launch date if Russian service module is delayed or Progress vehicle shortfall

RCM PDR Plan: July 1999	Reaction Control Module (RCM) is an option being reviewed to provide U.S. propulsion capability. Schedule estimate for RCM Program Design Review if authorization to proceed is provided in January 1999
RCM CDR Plan: February 2000	Estimated schedule for Reaction Control Module Critical Design Review if authorization to proceed is provided in January 1999
RCM-1 delivery Plan: August 2001	Estimated schedule for First Reaction Control Module delivery if authorization to proceed is provided in January 1999
RCS Interconnectivity Modifications, and Orbital Fluid Transfer System Plan: 2nd Qtr FY 2001	Provides orbiter mods to reaction control system (RCS) to enhance Shuttle reboost capability, and mechanisms to enable transfer of propellant between orbiters and ISS propulsion module. Orbiter fleet will be modified during Orbiter Maintenance Down Periods (OMDPs). Estimated schedule for first unit is second quarter of FY 2001.

ACCOMPLISHMENTS AND PLANS

In FY 1998, RPA major activities included continuation of FGB performance modifications, airlock modifications, and docking adapters. Activities accomplished in building the ICM include:

- Completion of design and requirement modifications
- Inspection and refurbishment of the primary structure
- Completion of the build and testing of the 110 lb Thruster Engine
- Receipt of both the active and passive Russian Androgynous Peripheral Assembly System (APAS) adapters

Funding totaling $200 million was originally identified in FY 1997 for RPA. Subsequent decisions and development problems slowed work on the ICM and associated flight and ground equipment and activities. The schedule for completion of the ICM has been extended. As a result, NRL informed NASA in mid-1998 that they would not be able to obligate FY 1997 funds as planned, prior to the end of FY 1998. NASA received approval of its revised FY 1997 operating plan to use $23 million of FY 1997 funds to initiate work on orbiter interconnectivity modifications. This will ensure the timely development of the orbiter design to enable modification of Orbiter Vehicle 102 during its upcoming Orbiter Maintenance Down Period (OMDP). The Shuttle fleet will be modified to augment existing Shuttle reboost capability for the ISS. This effort would be accomplished over the next several years. The first availability for this augmented orbiter reboost capability for ISS assembly is currently anticipated to be in the 2002/2003 time frame. A formal contract proposal from the Boeing Company and United Space Alliance is being evaluated.

FY 1999

- ICM activities include completion of all subsystem development, test and integration, flight software build and test, and preparation for shipment to the KSC launch site.

- Continue to perform prestart requirements analysis and long lead procurements to enable 2002 U.S. propulsion capability deployment. A decision will be made in early part of the second quarter of FY 1999 to authorize its procurement

- Orbiter interconnect design, development and hardware procurement activities for the Orbiter Reaction Control System enhancements.

- Docking module modifications will be performed on OV-102 during its maintenance down period to allow Columbia to rendezvous and dock with ISS for additional ISS logistics and reboost support.

- If authorization to proceed is provided in January 1999, the Preliminary Design review for a U.S. Reaction Control Module will likely occur in the last quarter of FY 1999

FY 2000

- The ICM is planned to be shipped to KSC early in FY 2000 where it will undergo End-to-End testing, launch processing, and shuttle integration if required to support a Russian shortfall.

- Pressurized logistics support carrier provided for the new logistics flights 5A.1 and 7A.1 resulting from Russian flight readiness delay of initial Progress flights to ISS and existing logistics backlog during the U.S. Laboratory deployment timeframe.

- During the OV-103 maintenance down period scheduled for the fourth quarter of the fiscal year, Discovery will become the first Shuttle to be outfitted with the Reaction Control System enhancements.

If authorization to proceed is provided in January 1999, the Critical Design review for a U.S. Reaction Control Module will likely occur in the first quarter of FY 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE STATION CREW RETURN VEHICLE

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Crew Return Vehicle	--	--	148,000

PROGRAM GOALS

The safety of the crew for the International Space Station is of critical importance. The Russian Soyuz vehicle has provided a contingency capability for life threatening emergencies that may arise during extended stays on orbit on the Mir and will do so for the initial years of the ISS. Continued reliance on the Soyuz limits the crew size for the ISS and poses significant operational and programmatic risks. Each Soyuz can only transport a crew of 3 and has to be changed out after about six months on orbit. A more capable crew return vehicle that overcomes the limitations of the Soyuz is viewed as the most viable long term approach for ensuring crew safety. A goal of the Crew Return Vehicle (CRV) project is to leverage the technologies, processes, test results, and designs developed in the preliminary technology development work carried out in the X-38 project and related contractor studies of a CRV.

The Crew Return Vehicle (CRV) project will provide an independent U.S. crew return capability for the ISS beginning in FY 2004 and will be sustained for the life of the Station. The CRV will accommodate safe return for up to seven crew under the following scenarios:

- Crew member(s) ill or injured while the space shuttle orbiter is not at the station
- Catastrophic failure of the station that makes it unable to support life and the space shuttle orbiter is not at the station or is unable to reach the station in the required time
- Problem with the space shuttle that makes it unavailable to re-supply the station or change-out crew in a required timeframe

STRATEGY FOR ACHIEVING GOALS

NASA has funded the X-38 project to develop more fully the technology and design basis for a CRV. The X-38 design has a strong foundation from the lifting body research and technology developments carried out since the 1960's. NASA will also take advantage of the related efforts which are more focussed on alternatives to the Space Shuttle to carry crew into orbit, as well as return crew from orbit. A final design decision on whether to follow the X-38 path or to incorporate alternative design concepts will be made in FY 2000. The decision will be closely tied to progress on the X-38, alternative design concepts, and the results of the Future Launch Studies. NASA's objective is to have the first vehicle available for deployment to the Space Station in 2004. which is focused on forming the foundation for generic low cost human-rated spacecraft.

If the X-38 path were selected, the transition from X-38 research and development to CRV design and development would occur in early FY 2000 as X-38 work phases out and CRV work phases in. This transition plan for the X-38 path is as follows:

- Phase 0 - An unfunded observation period in which contractors interact with the X-38 project team. This effort began 20 July 1998 and will run through Final RFP release for Phase 1 in March 1999. Five companies are currently participating in this phase. This phase is performed with X-38 Advanced Projects funding.
- Phase 1 - Multiple contractors will perform delta design tasks to convert the X-38 design into an operational CRV design and participate in flight-testing. The X-38 space flight test is currently scheduled to occur in the first half of FY 2000. At the end of Phase 1 (approximately 1 year) the final build-to-specification (or possible build-to-print) configuration of an X-38 based CRV will have been established. All drawings, prints, schematics, and software will be owned by the government at the end of Phase 1. As the transitional phase, Phase 1 is budgeted partially by X-38 Advanced Projects and partially by the CRV funding requested above.
- Phase 2 - Currently planned as a fixed price production of the CRVs by industry. The contractor will be selected by a competition based on the released drawings for the vehicle. This phase is budgeted by the CRV project.

These three phases will include three primary tasks:

- Perform delta design tasks necessary to convert the X-38 design into an operational CRV design, and perform necessary system integration internally and with STS and ISS.
- Perform atmospheric and space flight tests of X-38 prototype vehicles.
- Perform production of the CRV operational vehicles.

A total of four flight units are viewed as needed to meet ISS crew return requirements, assuming the ISS has at least one and perhaps two vehicles present on the Station at any time. The requirement for one or two CRVs on the station is currently as part of system trade studies.

SCHEDULE & OUTPUTS (X-38 PATH)

Start Contractor Observation period Plan: July 1998 Revised: Completed	Beginning of period in which potential contractors observe X-38 Program flight demonstration test and development activity.
CRV Request For Proposal release for Phase 1 Plan: March 1999 Revised: TBD	Release RFP for a funded period in which multiple contractors will perform delta design tasks to convert the X-38 design in an operational CRV design and participate in flight-testing.

Phase 1 Start Plan: October 1999 Revised: TBD	Multiple contractors will perform delta design tasks to convert the X-38 design in an operational CRV design and participate in flight-testing.
Design Freeze for Phase 2 RFP Plan: September 2000 Revised: TBD	Freeze CRV design based on X-38 experience to date and use for basis of CRV development contract.
Award CRV development contract Plan: December 2000 Revised: TBD	Contractor Award of CRV development contract.

ACCOMPLISHMENTS AND PLANS – FY 2000

In FY 2000 the design approach decision will be made for the CRV project. If the decision is to proceed with developing the design of the CRV using the X-38 space test vehicle as the basis of design, the following provides an indication of the design and development work which would be conducted, using both civil servants and contractors to firm up the design.

CRV Vehicle Subsystems

NASA Tasks

Avionics work would include continued development of the CRV inertial guidance system (SIGI – System of Interactive Guidance and Information); avionics instrumentation; radiation-hardened computer system network elements; operating system software; and communication system signal processors. Flight dynamics work would include simulation-based development and verification of the CRV flight controls. Mechanisms work will include delivery of electro-mechanical actuators (EMAs) and laser pyros, and EMA testing. Parafoil work would continue with testing, new parafoil procurements, and integrated structural dynamic modeling. Thermal Protection System component procurement will begin.

Phase 1 Contractor Tasks

Contractor tasks would be focussed on designs of avionics computers, networks and data busses; instrumentation and sensors; electrical power system; communications system; engineering support; laser altimeter; data recorder; avionics testbed; human computer interface; flight software; and interconnect wiring and connectors. Mechanisms work will be performed on the berthing/docking design and fin mechanisms. Manufacturing work would begin on the berthing/docking module; metallic structural parts materials and machining; composite structural parts materials and manufacturing; and tooling. Structures work would begin on structural, hatch, window and couch design.

Systems Engineering and Operations

Safety, Reliability, and Quality Assurance, and Systems Engineering and Integration work would be performed as NASA primary tasks supported by the Phase 1 contractors

Operations tasks include analyses of CRV separation (from Space Station) dynamics, continuing development of landing site and site selection requirements, and development of crew displays and controls requirements. Mission operations tasks include Mission Control Center and facility design requirements, modeling, and development of flight and ground procedures and flight rules. Logistics and maintenance tasks would focus on development of a spares program. Kennedy Space Center tasks include development of launch support and logistics flight operations requirements.

INTERNATIONAL SPACE STATION

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **U.S./RUSSIAN COOPERATION AND PROGRAM ASSURANCE**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998	FY 1999	FY 2000	Page Number
		(Thousands of Dollars)		
Russian Program Assurance	110,000	(248,300)	(200,000)	ISS 2-1
Total	110,000	(248,300)	(200,000)	
Distribution of Program Amount by Installation				
Johnson Space Center	101,600	--	--	
Marshall Space Flight Center	7,600	--	--	
Ames Research Center	700	--	--	
Goddard Space Flight Center	100	--	--	
Total	110,000	--	--	

PROGRAM GOALS

In FY 1997, the budget line item entitiled, U.S./Russian Cooperation and Program Assurance, was established. This budget line item had two parts, U.S./Russian Cooperation (Russian Space Agency contract support) and Russian Program Assurance (RPA). Funding for the first part has been completed. Ythe second part, Russina Program Assurance (RPA), was re-established within the Space Station budget line. The RPA budget was established to fund contigencies and backup capabiliites in response to concerns about the ability of the Russians to meet their ISS commitments. Tese concerns have been heightened by the slippage of the Russian service module (SM) from May 1998 to December 1998 and then to July 1999.

The United States (U.S.) and the Russian Federation have underway a three-phase joint cooperative space program to accomplish five major goals. First, the program permits us to develop, maintain, and enhance capabilities and operations to allow humans to live and work continuously in space. Second, by establishing a relationship with Russia as an international partner for the human exploration and exploration of space, the United States can reduce the cost of future U.S. space initiatives by applying Russian-developed technology. Third. by flying Space Shuttle missions to the Russian Mir, the United States can enhance its understanding of long-duration operations. and gain life sciences and microgravity research benefits from long-duration experimentation. Fourth, and of considerable importance, early cooperation with the Russians permits us to develop common systems and operating procedures which will increase the probability of success and mitigate risks in the design, assembly, and operation of the International Space Station (ISS)in which they are a full partner. Finally, this relationship between the U.S. and Russian space agencies advances U.S. national space programs as well as U.S. aerospace industry.

STRATEGY FOR ACHIEVING GOALS

The Russian Space Agency (RSA) contract provided services and hardware for Phase 1 and selected Phase II activities related to the ISS program. Phase I of the program expands the joint participation by U.S. and Russian crews in Mir and Space Shuttle operations. This expanded program used the unique capabilities of the Space Shuttle and the Russian Space Station Mir and provided support for nine flights to Mir, including seven long-duration stays of U.S. crew. Phase I provided valuable experience and test data which greatly reduced technical risks associated with the construction and operation of the ISS and provided early opportunities for extended scientific and research activities. The Russian Space Station's capabilities have been enhanced by contributions from both countries. The Space Shuttle delivered new Russian-built solar arrays to replace existing arrays on Mir. and one of these new arrays used solar cells provided by the U.S. Russia has launched the Spektr and Priroda modules to its station, equipped with U.S., Russian, and other international scientific hardware to support science and research experiments. In 1996. NASA exercised options to add an eighth and ninth shuttle flight to Mir. These additional flights will assist Russia in meeting its commitment to deliver key elements used in the early assembly of the ISS and permitted additional NASA astronauts to perform long-duration missions on Mir. The eighth and ninth Mir flights used the Space Shuttle to reduce a significant logistics shortfall on Mir. conduct vital engineering research and expand our knowledge and experience of the effects of long-duration weightlessness. This approach took into account the joint U.S./Russian interest in continuation of the Shuttle/Mir program, while minimizing changes to the ISS development plan.

During Phase I, the RSA provided management, Mir lifetime extension, Mir capabilities expansion, docking hardware and mission support for both long-duration and short-term, joint missions, Management activities included project documentation, and program and subcontract management. Mir lifetime extension included system requirements planning. communication and control systems analyses and upgrades, thermal control documentation and requirements definition, environmentally closed life support system (ECLSS) upgrades, power supply system upgrades, and propulsion systems documentation. To expand Mir capabilities, Russia and the U.S attached Spektr and Priroda modules to the Mir for scientific use.

Phase II combines U.S. and Russian hardware to create an advanced orbital research facility with early human-tended capability. This facility will significantly expand the scientific and research activities initiated in Phase I, and will form the early core of the ISS. Selected Phase II activities in the contract develop systems capabilities. support, and other infrastructure for the ISS. Under a fixed-price contractual arrangement with NASA, the RSA furnished supplies and/or services to enhance Mir operational capabilities. perform joint space flights, and conduct joint activities that will assist in the design, development, operations, and utilization of the

ISS. During this phase, the RSA also provides management, advanced technology, associated analyses, and ISS elements. ISS elements include: requirements definition of a joint airlock and delivery of androgynous peripheral docking system (APDS) hardware; service module modifications; FGB energy block modifications; delivery of repress/depress pumps for the airlock; and study and documentation related to a scientific power platform.

The U.S./Russian Cooperation and Program Assurance (RPA), as part one Step one, was initiated in May 1997. It provided contingency planning funds to address ISS program requirements resulting from delays on the part of Russia in meeting its commitments to the ISS program. The first step in the contingency plan, which was to protect against a potential further delay in the SM, has been implemented. The ISS program is purchasing an interim control module (ICM) from the U.S. Naval Research Laboratory (NRL) to provide attitude control and reboost functions for continuation of the ISS assembly sequence in case the Russian SM is launched later than July 1999. The NRL's ICM is currently being prepared to support a March 2000 launch to back up any shortfall of Progress fuel resupply vehicles. The Program is also maintaining an option to attach it to the back of the Russian-built functional cargo block (FGB), should the Russian Service Module slip considerably beyond its scheduled launch in July 1999.

Step One of NASA's RPA contingency plan had two primary components. First, modifications were done to the Zarya, an element purchased from Russia and owned by the U.S, to enhance the Zarya's propulsion control capabilities and make it refuelable. The Zarya was launched on November 20, 1998. Second, the development of an interim control module (ICM) is being pursued to ensure that sufficient attitude and reboost capability is available if required in the assembly sequence. The Zarya modifications and the ICM addition will enable the on-orbit build to continue even without the Russian Service Module, although not as planned due to the loss of the Service Module's habitation resources. This would result in increased risk due to the absence of an ISS-based crew to address real-time problems, which can be expected to arise. It would also result in lost research opportunities, resulting in a significant research gap or the introduction of new Shuttle based research opportunities. Other RPA activities included purchase of docking adapters and SM flight support equipment from RSA, airlock modifications, O^2 compressor for the airlock, and other related ICM tasks. In 1999, RPA funding for Step one will support the completion of assembly, test and checkout of the ICM.

The second step of the RPA program is addressed under the International Space Station narrative.

MEASURES OF PERFORMANCE

Delivery of docking mechanisms Plan: 1st, 2nd, 3rd Qtrs. FY 1998 Actual: August 1998	Delivery of androgynous peripheral attachment system (APAS, a docking mechanism) from Energia associated avionics and control panels for ISS/Shuttle.
ICM CDR Plan: December 1997 Actual: December 1997	NRL and ISS program office completed the critical design review (CDR) for the ICM

SM Launch Plan: December 1998 Revised: July 1999	The SM will be launched as part of the ISS Revision C Assembly Sequence Revised launch date per ISS Revision D Modified Assembly Sequence
FDRD Completed Plan: February 1998 Revised: February 1999	Flight design requirements document (FDRD) baseline established in order to allow Shuttle to begin flight design processes Revised per ISS Revision D Modified Assembly Sequence
Phase II GSR Plan: March 1998 Actual: March 1998	Phase II ground safety review (GSR) at KSC
Phase II FSR Plan: April 1998 Revised: January 1999	Phase II flight safety review (FSR) at JSC Revised per ISS Revision D Modified Assembly Sequence
Cargo Integration Review (CIR) Plan: April 1998 Actual: June 1999	Review of cargo element with Shuttle Program Revised per ISS Revision D Modified Assembly Sequence

ACCOMPLISHMENTS AND PLANS

In FY 1998, RPA major activities included continuation of FGB performance modifications, airlock modifications, and docking adapters. Activities accomplished in building the ICM included:

- Completion of desgin and requirement modifications;
- Inspection and refurbishment of the primary structure;
- Completion of the build and testing of the 110lb Thurster Engine; and
- Receipt of both the active and passive Russian androgynous peripheral assembly system (APAS) adapters

In FY 1999, this budget will be discontinued. A new budget line titled "Russian Program Assurance" will be established within the International Space Station program.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

FISCAL YEAR 2000 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

The Launch Vehicles and Payload Operations program is a key component of NASA's Human Exploration and Development of Space (HEDS) Enterprise, which has as its ultimate mission to open the space frontier by exploring, using and enabling the development of space. Our current launch vehicle and payload operations programs provide safe, assured transportation to and from space for people and payloads, in order to enhance scientific knowledge, support technology development, and enable commercial activity. In addition, this budget accounts supports the four major goals of the HEDS program which are: (1) Increase human knowledge of nature's processes using the space environment; (2) Explore the solar system; (3) Achieve routine space travel; and (4) Enrich life on Earth through people living and working in space.

STRATEGY FOR ACHIEVING GOALS

In Launch Vehicles and Payload Operations, we are committed to ensuring effective, efficient and safe transportation to and from space, while continually seeking to improve the safety margin of the Space Shuttle. We are actively seeking opportunities to reduce operational costs, improve performance on development projects and to selectively enhance capabilities to meet customer needs.

Through the utilization of the Space Shuttle and ELVs, we will ensure that capabilities are maintained to provide access to space that enables the development of advanced space systems, technologies, and materials. In providing these capabilities, we will ensure that our workforce, our most important resource, will have management support to meet operational and future program requirements through career development training and employee recognition programs.

Recognizing the national benefits derived from past Space Shuttle activities, we will continue to emphasize the HEDS contribution to the national community. These contributions include science and engineering educational opportunities for our youth, collaborative relationships with industry, and improved quality of life through advanced technology, provided both directly to the private sector and through "spinoffs".

Space Shuttle achievements in exploration and development of space have paved the way for enhancing our nation's leadership in expanding human presence in space. The necessity to fly safely and the requirement to satisfy payload customer needs, while striving to reduce operations costs will be the dominant programmatic thrusts throughout the next decade. The success of the Space Shuttle in achieving HEDS goals and objectives will play a central role in leading our Nation to future discoveries and technological advances that will benefit us all.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

FISCAL YEAR 2000 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1998	FY 1999	FY 2000
LAUNCH VEHICLES AND PAYLOAD OPERATIONS	**3,118.2**	**3,175.3**	**3,155.3**
SPACE SHUTTLE	2,912.8	2,998.3	2,986.2
PAYLOAD UTILIZATION AND OPERATIONS	205.4	177.0	169.1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1998	FY 1999	FY2000
LAUNCH VEHICLES AND PAYLOAD OPERATIONS	**60.5**	**208.9**	**205.1**
SPACE SHUTTLE	27.1	70.6	20.0
PAYLOAD UTILIZATION AND OPERATIONS	33.4	138.3	185.1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

DISTRIBUTION OF LAUNCH VEHICLES AND PAYLOAD OPERATIONS BY INSTALLATION
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Space Shuttle	1998	2.912.800	1.637.197	156.817	1.060.118	45.716	652	5.800	220	0	2.669	102	3.509
	1999	2.998.300	1.737.100	162.700	1.055.700	31.800	2.200	4.000	200	0	500	100	4.000
	2000	2.986.200	1.745.700	170.900	1.025.600	34.000	1.600	4.000	200	0	600	100	3.500
Payload Utilization and Operations	1998	205.400	83.209	52.541	53.450	1.500	500	0	132	750	9.800	0	3.518
	1999	177.000	35.500	67.600	49.600	1.500	0	0	0	0	12.800	0	10.000
	2000	169.100	37.800	79.000	41.500	1.600	0	0	0	0	8.200	0	1.000
TOTAL LAUNCH VEHICLES & PAYLOAD OPERATIONS	1998	3.118.200	1.720.406	209.358	1.113.568	47.216	1.152	5.800	352	750	12.469	102	7.027
	1999	3.175.300	1.772.600	230.300	1.105.300	33.300	2.200	4.000	200	0	13.300	100	14.000
	2000	3.155.300	1.783.500	249.900	1.067.100	35.600	1.600	4.000	200	0	8.800	100	4.500

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT | **SPACE SHUTTLE**

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Safety and performance upgrades	568,400	571,600	438,800	HSF 3-5
Shuttle operations	2,344,400	2,426,700	2,547,400	HSF 3-20
Total	2,912,800	2,998,300	2,986,200	

Distribution of Program Amount by Installation

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET
Johnson Space Center	1,637,197	1,737,100	1,745,700
Kennedy Space Center	156,817	162,700	170,900
Marshall Space Flight Center	1,060,118	1,055,700	1,025,600
Stennis Space Center	45,716	31,800	34,000
Dryden Flight Research Center	5,800	4,000	4,000
Ames Research Center	652	2,200	1,600
Langley Research Center	220	200	200
Goddard Space Flight Center	2,669	500	600
Jet Propulsion Laboratory	102	100	100
Headquarters	3,509	4,000	3,500
Total	2,912,800	2,998,300	2,986,200

GENERAL

The Space Shuttle program provides launch services to a diverse set of customers, supporting payloads that range from small hand-held experiments to large laboratories. While most missions are devoted to NASA-sponsored payloads, industry, partnerships, corporations, academia, national and international agencies exercise wide participation. Both NASA and the U.S. and international scientific communities are beneficiaries of this approach. The Space Shuttle is a domestically and internationally sought-after research facility because of its unique ability to provide on-orbit crew operations, rendezvous/retrieval, and payload provisions, including power, telemetry, pointing and active cooling.

The Space Shuttle continues to prove to be the most versatile launch vehicle ever built. This has been demonstrated by: (1) rendezvous missions with the Russian Space Station Mir; (2) advancing life sciences and technology through long-duration Spacelab and Spacehab missions; and (3) repairing and servicing the Hubble Space Telescope, enabling discovery of new astronomical events. The Space Shuttle has also performed rescue and retrieval of spacecraft, and has begun the assembly of the International Space Station. The Space Shuttle services numerous cooperative and reimbursable payloads involving foreign governments and international agencies. The current focus of international cooperation, for which the Space Shuttle is uniquely suited, is the assembly and operational support of the International Space Station (ISS), which began in FY 1999.

The Space Shuttle program participates in the domestic commercial development of space, providing flight opportunities to NASA's Centers for Commercial Development of Space. These non-profit consortia of industry, academia, and government were created to conduct commercially applied research activities by encouraging industry involvement leading to new products and services through access to the space environment. Cooperative activities with the National Institutes of Health (NIH), the National Science Foundation (NSF), the Department of Defense [DoD] and other U.S. agencies are advancing research that is generating new knowledge in health, medicine, science, and technology. Space Shuttle support for the flight of Neurolab in FY 1998, a major cooperative NASA-NIH program, and the Shuttle Radar Topography Mission, a joint DoD/NASA payload in FY 1999, are prime examples.

The Space Shuttle budget is divided into two categories: Safety and Performance Upgrades (S&PU) and Shuttle Operations. It is distributed to the various program elements primarily through the four Human Space Flight Centers, Dryden Flight Research Center, and the Ames Research Center. Safety and Performance Upgrades provide for modifications and improvements to the flight elements and ground facilities, including expansion of safety and operating margins and enhancement of Space Shuttle capabilities as well as the replacement of obsolete systems. Shuttle Operations includes hardware production, ground processing, launch and landing, mission operations, flight crew operations, training, logistics, and sustaining engineering. In addition, this budget includes funding for facilities related to the Space Shuttle.

The restructuring activities of the past seven years have resulted in constant dollar savings of 30% by FY 1998, equating to 32% less workforce since FY 1992. Reliability has improved and since FY 1995, 25 missions have been launched within the first five minutes of the launch window, an 86% success rate. In addition, after 93 successful missions, a significant reduction in operational requirements is continuing. Consolidation of contracts to a single prime contract is progressing successfully since the award of the Space Flight Operations Contract (SFOC) on October 1, 1996. Phase II of the transition is now underway, with the first production hardware contract (Solid Rocket Booster) transferred into SFOC in FY 1998. The total transition is scheduled to be complete by FY 2001.

PROGRAM GOALS

The primary goals of the Space Shuttle program in priority order are: (1) fly safely; (2) meet the flight manifest; (3) improve supportability, and (4) improve the system. Reduction in program costs is a continuing program objective made possible by accomplishment of these four goals.

STRATEGY FOR ACHIEVING GOALS

All decisions regarding program requirements, programmatic changes and budget reductions are guided by the program's goals as stated above. The overall strategy for the Shuttle Operations budget is to request funding levels sufficient to allow the Space Flight Operations Contract to meet the intended flight rates. This includes appropriate contingency planning in both budget and schedule allowances to assure transportation and assembly support to the Space Station program, while at the same time incentivizing the contractor to identify opportunities for reductions in operations costs while still ensuring the safe and reliable operation of the Space Shuttle. The continued transition of activities to the Space Flight Operations Contract represents a key element of this strategy.

This budget is based on an average of seven flights annually with a surge capability to nine flights and remains essentially unchanged from previous years. Although FY 1998 had only four flights, and six flights are planned for FY 1999, an eight-flight year is planned for FY 2000 that includes the third Hubble Space Telescope servicing mission. FY 2001 is a nine-flight year with the X-38 Flight Demonstration, and a research mission which will include the Triana spacecraft. The budgeted flight rate is anticipated to continue at eight per year through FY 2003 and seven flights in FY 2004, although the capability to adjust this flight rate as cionditions warrant is retained. This represents a no change in the total number of flights during this time period from previous submissions. This manifest supports the Nation's science and technology objectives through scheduled Spacehab and other science missions, and commencement of assembly of the International Space Station.

In addition to flying safely, restructuring the program, and conducting a single prime consolidation, NASA is continuing the Safety and Performance Upgrades program. The Space Shuttle program's strategy for the Safety and Performance Upgrades budget is to fund those modifications and improvements which will provide for the safe, continuous, and affordable operations of the Space Shuttle system for the foreseeable future. This is an essential element of the launch strategy required for continuing supportability to the International Space Station. Completion of selected projects, termed "Phase I" upgrades, has improved Space Shuttle safety and increased payload-to-orbit performance by 13,000 pounds. The additional payload-to-orbit performance allows the Orbiter to achieve the orbital inclination and altitude of the International Space Station. The largest of these projects was the Super LightWeight Tank (SLWT) which was successfully flown on STS-91. Completion of the Phase I upgrades has enabled the Space Shuttle to meet the performance requirements of the first Space Station assembly flight, STS-88, in the 1st quarter of FY 1999. "Phase II" upgrades have been added to the program to assure continued mission supportability into the next century.

As noted in the Space Shuttle's FY 1999 Congressional request, the Agency formed a Space Transportation Council (STC) to assess advanced transportation areas in both the Office of Space Flight and the Office of Aeronautics and Space Transportation Technology (now called Aero-Space Technology). Technology need studies were conducted by the Space Shuttle program in FY 1998 and are continuing in FY 1999. In recognition of the value of close collaboration on the technology needs of future reusable launch vehicles, lead responsibility has been consolidated within the Space Transportation Technology program. The Space Transportation Council will provide management oversight and policy direction across the agency's activities in this area. Potential major Shuttle upgrades will be examined under the Future Space Launch industry-led trade studies described in the Space Transportation Technology section. These studies will provide the basis for end-of-decade decisions by NASA and the Administration on pursuing an operational launch system to reduce NASA's launch cost.

BASIS OF FY 2000 FUNDING REQUIREMENT

SAFETY AND PERFORMANCE UPGRADES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Orbiter improvements	232,500	234,800	196,600
Multifunction-electronic display system	29,100	9,800	--
Other orbiter improvements	203,400	177,000	155,400
Supportability Upgrades	[50,000]	48,000	41,200
Propulsion upgrades	172,000	175,700	118,700
Space shuttle main engine upgrades	170,100	167,700	106,600
[Alternate Turbopump program]	[56,500]	[56,900]	[29,200]
[Large Throat Main Combustion Chamber]	[9,400]	[5,000]	--
[Phase II+ Powerhead Retrofit]	[9,200]	[6,600]	[600]
[Other main engine upgrades]	[95,000]	[99,200]	[76,800]
Solid rocket booster improvements	1,200	2,500	1,600
Super lightweight tank	700	1,500	--
Supportability Upgrades	[4,000]	4,000	10,500
Flight operations & launch site equipment upgrades	155,700	153,500	112,500
Flight operation upgrades	40,300	58,500	34,200
Launch site equipment upgrades	115,400	47,000	30,000
Supportability Upgrades	[41,000]	48,000	48,300
Construction of facilities	8,200	7,600	11,000
Total	568,400	571,600	438,800

GENERAL

The Safety and Performance Upgrade program is measured by the success it has in accomplishing the ongoing projects consistent with approved schedule and cost planning, and also the effect these projects have on the overall operation of the Space Shuttle System. Success depends on developing these projects and getting them implemented to help ensure the Space Shuttle's safe operation, and improve the reliability of the supporting elements. The reductions from FY 1999 to FY 2000 reflect the completion/phasedown of several projects as they near or reach their conclusions. The Alternate Turbopump Program (ATP), the Multifunction Electronic Display System (MEDS) and the Mission Control Center development all have significant reductions in FY 2000 as they near completion.

This budget request includes activities in the following categories: Orbiter Improvements, Propulsion Upgrades, Launch Site Equipment (LSE) Upgrades and Flight Operations Upgrades, as well as specific, Space Shuttle-related Construction of Facilities. This budget also includes Supportability upgrades to develop systems, which will combat obsolescence of vehicle and ground systems in order to maintain the program's viability into the next century. Vendor loss of aging components, high failure rates of older components, high repair costs of Shuttle-specific devices, and negative environmental impacts of some out-dated technologies are areas to be addressed. The following is a brief description of these activities.

Orbiter Improvements

The Orbiter improvements program provides for enhancements of the Space Shuttle systems, produces space components that are not susceptible to damage, and maintains core skills and capabilities required modifying and maintaining the Orbiter as a safe and effective transportation and science platform. These activities are provided by contract arrangements with Boeing North American (formerly, the Rockwell International Space Division) in two major locations: the Downey, California facility provides engineering, manufacturing and testing; and the Palmdale, California operation provides Orbiter Maintenance Down Period (OMDP) support as discussed below. Other activities that support this effort are subsystem management engineering and analysis conducted by Lockheed-Martin Corporation and development and modifications required for support to the extravehicular capability conducted by Hamilton Standard.

Orbiter Maintenance Down Period (OMDP) occurs when an Orbiter is routinely taken out of service (about once every five years) for detailed structural inspections and thorough testing of its systems before returning to operational status. This period also provides opportunities for major modifications and upgrades, especially those upgrades that are necessary for improving performance to meet the International Space Station operational profile.

Propulsion Upgrades

The main engine safety and performance upgrade program is managed by the Marshall Space Flight Center (MSFC) and supports the Orbiter fleet with flight-qualified main engine components and the necessary engineering and manufacturing capability to address any failure or anomaly quickly. The Rocketdyne Division of the Boeing North American Corporation is responsible for operating three locations that provide engine manufacturing, major overhaul, components recycle and test. They are:

(1) Canoga Park, California which manufactures and performs major overhaul to the main engines;
(2) Stennis Space Center (SSC), Mississippi for conducting engine development, acceptance and certification tests; and
(3) Kennedy Space Center (KSC), Florida for engine inspection checkout activities

The Marshall Space Flight Center (MSFC) manages engine ground test and flight data evaluation, hardware anomaly reviews, and anomaly resolution. The Alternate Turbopump project is also managed by the MSFC under contract with Pratt Whitney of West Palm Beach, FL.

The Super Lightweight Tank project is managed by the MSFC and is being accomplished by the Lockheed Martin Corporation at the government-owned Michoud Assembly Facility (MAF) near New Orleans, LA.

Flight Operations and Launch Site Equipment Upgrades

The major flight operations facilities at Johnson Space Center (JSC) include the Mission Control Center (MCC), the flight and ground support training facilities, the flight design systems and the training aircraft fleet that includes the Space Shuttle training aircraft, and the T-38 aircraft.

The major launch site operational facilities at KSC include three Orbiter Processing Facilities (OPFs), two launch pads, the Vehicle Assembly Building (VAB), the Launch Control Center (LCC), and three Mobile Launcher Platforms (MLPs). The most significant upgrade in this account is the Checkout and Launch Control System at KSC.

Construction of Facilities

Construction of Facilities (CofF) funding for Space Shuttle projects is provided in this budget to refurbish, modify, reclaim, replace and restore facilities at Office of Space Flight Centers to improve performance, address environmental concerns of the older facilities, and to ensure their readiness to support the Space Shuttle Operations.

PROGRAM GOALS

NASA policy planning assumes the Space Shuttle will need to be capable of supporting the critical transportation requirements for the assembly of the Space Station and perhaps through 10 years of Space Station operations. In order to maintain a viable, human transportation capability that will operate into the next century and support NASA's launch requirements, specific program investments are required. These investments are consistent with NASA's strategy of ensuring the Space Shuttle remains viable until a new transportation system is operational.

STRATEGY FOR ACHIEVING GOALS

This budget provides funding required for modifying and improving the capability of the Space Shuttle to ensure its viability as a safe, effective transportation system and scientific platform. It also addresses increasingly stringent environmental requirements, obsolescence of subsystems in the flight vehicle and on the ground, and capital investments needed to achieve reductions in operational costs. Work continues on the Alternate Fuel Turbopump for the planned introduction of the Block II Space Shuttle Main Engine (SSME). The Block IIA engines flew on STS-89 in January 1998 and the Block II will fly in FY 2000.

In the Space Shuttle's FY 1999 Congressional request the Agency formed a Space Transportation Council (STC) to assess advanced transportation areas in both the Office of Space Flight and the Office of Aeronautics and Space Transportation Technology (now called Aero-Space Technology). Technology need studies were conducted by the Space Shuttle program in FY 1998 and are continuing in FY 1999. In recognition of the value of close collaboration on the technology needs of future reusable launch vehicles, lead responsibility has been consolidated within the Space Transportation Technology program. The Space Transportation Council will provide management oversight and policy direction across the agency's activities in this area. Potential major Shuttle upgrades will be examined under the Future Space Launch industry-led trade studies described in the Space Transportation Technology section. These studies will provide the basis for end-of-decade decisions by NASA and the Administration on pursuing an operational launch system to reduce NASA's launch cost.

The major safety and performance upgrades and their initial flight dates are listed on the following chart on the next page.

SCHEDULE AND OUTPUTS

The Safety and Performance Upgrade program is measured by the success it has in accomplishing the ongoing projects consistent with approved schedule and cost planning. Success depends on developing/implementing these projects to help ensure the Space Shuttle's safe operation, improve the reliability of the supporting elements, and improve efficiencies to reduce operational costs. This budget addresses all elements of the Space Shuttle program and is managed through an approval process that ensures that new projects are evaluated, approved and initiated on a priority basis, and that existing projects meet established cost and schedule goals. Significant milestones are listed on the next page:

Orbiter Improvements

Multifunction Electronic-Display System (MEDS) - MEDS is a state-of-the-art integrated display system that will replace the current Orbiter cockpit displays with an integrated liquid crystal display system.

Complete MEDS Qualification Testing	Complete hardware qualification testing and start hardware integration and verification testing.
Plan: 1st Qtr FY 1996 Actual: 1st Qtr FY 1998	The qualification program was extended through this date. No significant impact to initial operating capability is expected. Delay was due to change in glass supplier.
OV-104 Major MOD Plan: 2nd Qtr FY 1998 Actual: 3rd Qtr FY 1998	Installation and checkout of MEDS hardware in OV-104 at Palmdale
MEDS Initial Operational Capability (IOC) Plan: 2nd Qtr FY 1999 Revised: 4th Qtr FY 1999	First flight of a MEDS equipped Orbiter. (OV-104/STS-92)

Global Positioning System (GPS) - GPS will replace the current TACAN navigational system in the Orbiter navigation system when the military TACAN ground stations will be phased out in the year 2000. The planned readiness date for the Space Shuttle's system is FY 1999.

Complete GPS System Requirements Review Plan: 2nd Qtr FY 1997 Actual: 1st Qtr FY 1998	Completion of CDR will allow drawings to be released for production to proceed. Delay is due to the change from the original, single-string GPS, to the three-string GPS System.
TACAN Removal Plan: 3rd Qtr FY 1998 Actual: 3rd Qtr FY 1998	Remove TACAN from OV-104 at Palmdale based on November 1997 go/no go decision.
Orbiter Install Complete Plan: 4th Qtr FY 1998 Revised: 2nd Qtr FY 1999	Installation and checkout of hardware on OV-104 at Palmdale.
Complete GPS operational Capability Plan: 2nd Qtr FY 1999 Revised: Under Assessment	Initial operation of GPS without TACAN system. Due to technical problems, the GPS has been removed from OV-104 and the TACAN system is being reinstalled. Initial operations of GPS without TACN is still under assessment.

Orbiter Maintenance Down Periods (OMDP)

Initiate Atlantis (OV-104) OMDP Plan: 1st Qtr FY 1998 Actual: 1st Qtr FY 1998	Conduct routine maintenance and structural inspection. Also install an external airlock, the MEDS upgrade, and hardware for 3-String GPS capability.
Initiate Columbia (OV-102) OMDP Plan: 1st Qtr FY 1999 Revised: 3rd Qtr FY 1999	Conduct routine maintenance and structural inspection. Also, install the MEDS upgrade, hardware for 3-string GPS capability, and OV-102 scarring mods. Revised due to technical problems causing delays in the launch of AXAF.
Initiate Discovery (OV-103) OMDP Plan: 3rd Qtr FY 2000	Conduct routine maintenance and structural inspection. Also, install the MEDS upgrade, hardware for 3-string GPS capability.

Propulsion Upgrades

Super Lightweight Tank - This performance enhancement is designed to provide 7,500 pounds of additional performance for the Space Shuttle to allow rendezvous and operations with the International Space Station. Development was completed in FY 1997 with the successful proof test of the first unit.

Deliver first SLWT to KSC for flight Plan: 4th Qtr FY 1997 Actual: 2nd Qtr FY 1998	Final assembly and checkout will be conducted at the Michoud Assembly Facility (MAF) in New Orleans, Louisiana. Schedule revision was due to need to perform multiple proof tests to verify welds.
Fly first SLWT Plan: 3rd Qtr FY 1998 Actual: 3rd Qtr FY 1998	Successfully flew first SLWT on STS-91 (June 1998)

Space Shuttle Main Engine Safety Improvements - Introduction of Block I and Block II changes into the Space Shuttle's Main Engine program will improve the margin of safety by a factor of two. The interim Block IIA configuration (Block I without the High-Pressure Fuel Turbo Pump (HPFTP)) implements the safety and performance margins provided by the large throat main combustion chamber (LTMCC) while the HPFTP development problems are solved. The last Block IIA flight is planned for FY 1999.

High Pressure Fuel Turbopump CDR	Completion of Critical Design Review (CDR) will allow production to proceed for implementation of the Alternate Turbopump high-pressure fuel pump into the Block II Engine upgrade.
Plan: 3rd Qtr FY 1996	
Revised: 2nd Qtr FY 1997	Revised due to testing delays
Revised: 1st Qtr FY 1998	Opted for IIA configuration because of HPFTP design delays
Revised: 3rd Qtr FY 1998	Revised due to turbine housing redesign
Revised: 2nd Qtr FY 1999	Turbine housing redesign is still in work.
First flight of Block II engine	The high-pressure fuel turbopump will be combined with the LTMCC and Block I upgrades.
Plan: 4th Qtr FY 1997	
Revised: 1st Qtr FY 1998	Revised due to testing delays
Revised: 2nd Qtr FY 1998	Opted for IIA configuration because of HPFTP design delays.
Revised: 4th Qtr FY 1998	Revised due to turbine housing redesign.
Revised: 1st Qtr FY 2000	Turbine housing redesign is still in work.

Flight Operations and Launch Site Equipment Upgrades- Upgrades to the Mission Control Center were completed in FY 1998 period which improved operations reliability and maintainability and also took advantage of the state-of-the-art technology in displays and controls. In addition, upgrades continued in FY 1998 to the Launch Site Equipment at KSC, which will increase reliability and reduce obsolescence.

CLCS "Redstone" Delivery Plan: 1st Qtr FY 1998 Actual: 1st Qtr FY 1998	The initial delivery of requirements in the CLCS development, Redstone included the Super Light Weight Tanking Test Displays, a Robust Web interface, Four Prototype Consoles for User Evaluation and Initial System and application services.
CLCS "Thor" Delivery Plan: 3rd Qtr FY 1998 Actual: 3rd, 4th Qtr FY 1998	The second scheduled delivery in the CLCS development, Thor included System Services enhancements, System stress testing and end item management services, launch data bus phase 1 support and initial PCM support.
Orbiter Power Up/Down Application S/W Complete Plan: 2nd Qtr FY 1999	Orbiter vehicle power up and power down sequences can be initiated and monitored through the CLCS
CLCS Shuttle Processing Flow Capable Plan: 4th Qtr FY 2000	CLCS will be fully capable of supporting KSC orbiter pre-flight processing.
First Launch Using CLCS Plan: 1st Qtr FY 2001	Launch the first Shuttle from a CLCS – equipped Launch Control Center.
Complete Migration of CLCS to all Firing Rooms and Simulators Plan: 4th Qtr FY 2001	CLCS is fully operational for flight support. This will result in a significant reduction in operating cost, up to 50%, of the current LPS.

Construction of Facilities

Complete Phase I Restore Firex Pumps and Piping at LC-39 Plan: 3rd Qtr FY 1999	Restoration is needed. Pumps are currently inadequate to provide spray coverage during an emergency. This project replaces underrated firex loop piping and components, and provides fire protection for the Orbiter Mid-Body Umbilical Unit (OMBUU) at Pads A and B. Additional work was necessary to complete the associated controls, including control cable installation and termination on Pad B. Final work scheduled to be complete during Pad A modification period in FY 1999.

Complete Phase II Restore Firex Pumps and Piping at LC-39 Plan: 3rd Qtr FY 1999	Restoration is needed. Pumps are currently inadequate to provide spray coverage during an emergency. This project removes and replaces existing Firex pumps, motors, refurbishes diesels, and installs a new underground pipe between the pump station and Pads A and B.
Complete Phase II Replace Component Refurbishment and Chemical Analysis Facility at KSC	This facility was in non-compliance with OSHA standards and overcrowded and insulated with asbestos.
Plan: 4th Qtr. FY 97 Actual: 1st Qtr. FY 98	Complete activation of component refurbishment chemical analysis (CRCA) building.
Complete SSME Processing Facility at KSC Plan: 2nd Qtr. FY 98 Actual: 4th Qtr. FY 98	Project provides for construction of an addition to the east end of the lower level of OPF-3 Annex to provide shop area for SSME processing. The facility will allow for safely and efficiently processing engines.
Rehabilitation of 480V Electrical Distribution System at MAF	External Tank manufacturing building Rehabilitation of the 480V Electrical Distribution System is a 4 phase project. Each phase will be implemented in the main manufacturing areas of building 103. Project Phasing and scope for each phase:
Complete Phase I Plan: 2nd Qtr. FY 99	Phase I, Final Assembly Area Project will upgrade the power distribution system from below the substation to the respective tools (Labor-intensive project working over flight hardware).
Start Phase II Plan: 1st Qtr. FY 98 Actual: 1st Qtr FY 98	Phase II, ET Sub-Assembly Area Project will upgrade the power distribution system from below the substation to the respective tools. Completion of this phase is expected in the 1st quarter of FY 2000
Start Phase III Plan: 1st Qtr. FY 99	Phase III, Substations Nos. 17A/17B will replace the core system, Transformers and switch gear, breakers and oil switches. Include some down stream cable, cable tray, and panel upgrades. Planned completion date for this phase is first quarter of FY 2001.
Start Phase IV Plan: 1st Qtr. FY 00	Phase IV, Substations Nos., 7B, 4 & 5 - core system, transformers and switchgear, breakers and oil switches. Planned completion date for this phase is second quarter of FY 2001.
Complete Pad B Chiller Replacement at LC-39 Plan: 2nd Qtr. FY 99	This project replaces the aged facility chillers at Launch Complex 39, Pad B, and reconfigures the system for more efficient maintenance.

Milestone	Description
Complete Rehabilitation of High Pressure Industrial Water System at SSC Plan: 2nd Qtr. FY 99	This project initiates the restoration of the High Pressure Industrial Water Plant to ensure system reliability in support of the Space Shuttle Main Engine testing.
Start Restoration of Pad A PCR Wall and Ceiling Integrity at Launch Complex (LC)-39 Plan: 3rd Qtr. FY 98 Actual: 1st Qtr FY 99	This project provides for repair and replacement of damaged Payload Change Out Room (PCR) wall panels (Sides 1, 2, 3, & 4), replacement or elimination of deteriorated and leaking access doors, and other needed replacement and restoration. The modification will eliminate degrading flexducts and filter housings, improve pressurization of the PCR, provide an even distribution of air flow, and provide safe personnel access for maintenance and repair.
Start Pad A Surface and Slope Restoration at LC-39 Plan: 3rd Qtr. FY 98 Actual: 1st Qtr FY 99	This project provides for repair of the Pad A surface concrete, pad slopes, and the crawlerway grid path.
Complete Restoration of Pad A PCR Wall and Ceiling Integrity at Launch Complex (LC)-39 Plan: 1st Qtr. FY 00	
Complete Pad A Surface and Slope Restoration at LC-39 Plan: 1st Qtr. FY 00	This project provides for repair of the Pad A surface concrete, pad slopes, and the crawlerway grid path.
Start Repair of Pad A Flame Deflector & Trench at LC-39 Plan: 1st Qtr. FY 99 Actual: 1st Qtr. FY 99	This project provides for repair of the fire resistant surface of the Main and SRB flame deflector, repair/replacement of damaged and corroded structural members, and repair/replacement of bricks in the Flame Trench wall.
Complete Repair of Pad A Flame Deflector & Trench at LC-39 Plan: 1st Qtr. FY 00	This project provides for repair of the fire resistant surface of the Main and SRB flame deflector, repair/replacement of damaged and corroded structural members, and repair/replacement of bricks in the Flame Trench wall.

Start Pad A FSS Elevator restoration at LC-39 Plan: 1st Qtr. FY 99 Actual: 1st Qtr. FY 99 **Completion** **Plan: 1st Qtr. FY 00**	This project modifies the elevator structural on Pad B, and refurbishes the elevator cabs, cables and cableway.
Complete Pad A FSS Elevator restoration at LC-39 Plan: 1st Qtr. FY 00	
Cell E Restoration Start Plan: 3rd Qtr FY 99	This project restores and modifies the common solution return systems and lining for the cell. The cell lining is breaking down and requires restoration work at Michoud Assembly Facility.
Towway Support (Phase II) Start Plan: 2nd Qtr. FY 99	This project is the SSP portion of the Support Facility at the Towway of the SLF. This project will refurbish the SLF Convoy Operations capability at the SLF. Scheduled for completion in the 4th Quarter. of FY 2000.

ACCOMPLISHMENTS AND PLANS

A significant portion of the Safety and Performance Upgrades (S&PU) budget is dedicated to avoiding and preventing deleterious and costly effects of obsolescence, especially at a time when the program is undertaking the challenge of reducing the costs of operations. This portion of the budget contains projects that impact every element of the Space Shuttle vehicle. The S&PU budget will continue to support the replacement of the Orbiters' cockpit displays with Multifunction Electronic Display System (MEDS), replacing Tactical Air Command and Navigation System (TACAN) with Global Positioning System (GPS), and upgrading the T-38 aircraft with maintainable systems. Replacing elements of the launch site complex, upgrading major elements of the training facilities at Johnson Space Center, testing of main engine components at SSC, testing of Orbiter reaction control systems at the White Sands Test Facility, and replacing critical subsystems at the KSC facility complex are also funded.

In addition, this request includes funds for Shuttle Supportability Upgrades, which will maintain availability of the Space Shuttle fleet for the foreseeable future.

The Space Shuttle program rationale for supportability upgrades is founded on the premise that safety, reliability, and mission supportability improvements must be made in the Shuttle system to continue to provide safe and affordable operations into the next century. These will enable safe and efficient Shuttle operations during the Space Station era while providing a robust testbed for advanced technologies and a variety of customers.

The Space Shuttle Upgrade activity will be planned and implemented from a system-wide perspective. Individual upgrades will be integrated and prioritized across all flight and ground systems, ensuring that the upgrade is compatible with the entire program and other improvements. Selection of new upgrades through the review process approved by the Associate Administrator for Space Flight, the Program Management Council (PMC) and the Administrator will be utilized. Implementation authority and responsibility is delegated to the Lead Center Director for the Shuttle Program with the Shuttle Program Manager and the projects. Space Shuttle upgrades will be developed and implemented in a phased manner supporting one or more of the following program goals:

- Fly safely
- Meet the manifest
- Improve supportability: and
- Improve the system

The phasing strategy will be coordinated with the Reusable Launch Vehicle (RLV) project management, and other development projects, to capture common technology developments, while meeting the Shuttle manifest. This phasing strategy should allow the incorporation of additional, more comprehensive upgrades to the Space Shuttle system while benefiting other programs and technologies. Candidate upgrades in the initial phases will utilize state-of-the-art technology and provide safety/reliability, supportability, and/or cost (improvement) advantages. Candidate designs in the initial phases would maintain the current Shuttle mold lines and system/subsystem interfaces.

Orbiter Improvements

Orbiter improvements provide for modifications and upgrades to ensure compatibility of the Space Shuttle vehicles with the new Space Station operational environment. Orbiter weight reductions have been identified where operating experience or updated requirements allow selected items to be changed without impact to crew safety or mission success. These reductions include changing the exterior thermal protection materials on certain portions of the Orbiter: deleting portions of the Orbital Maneuvering and Reaction Control Systems (OMS/RCS) that are no longer required: changing the materia1 on the "flipper doors" that provide a seal between the Orbiter wing and its control surfaces: and development of lighter weight crew seats for the cockpit.

Other Orbiter improvements included new Digital Autopilot (DAP) software designed to reduce fuel consumption in orbit, and new launch trajectory software to increase performance margins and enable the deletion of the Bermuda tracking station for communications during launch.

The Multifunction Electronic Display System (MEDS) upgrade will replace the current Orbiter cockpit displays that are early 1970's technology. The current displays which provide command and control of the Space Shuttle are "single string" electro-mechanical devices that are experiencing life related failures and are maintenance intensive. Difficulty in obtaining parts, some of which are no longer manufactured, is becoming more prevalent. The MEDS upgrade is a state-of-the-art, multiple redundant liquid crystal display (LCD) system. MEDS will enhance the reliability of the cockpit display system, resolve the parts availability problem, and provide a much more flexible and capable display system for the crew. This upgrade will bring the Orbiter up to current aircraft standards, benefiting the training of new astronauts directly. Secondary benefits of MEDS are reductions in the Orbiter's weight and power consumption. The MEDS upgrade includes the design effort and production of modification kits for the four Orbiter vehicles. New MEDS ground support hardware is also being designed. When procured and installed it will upgrade the appropriate simulators, test equipment, and laboratories. MEDS will be installed in the Orbiters and tested during the planned OMDPs.

In FY 1998, Atlantis (OV-104) entered OMDP for normal maintenance, structural inspections, installation of the MEDS upgrade, and was successfully modified for docking with the International Space Station. In FY 1999, Columbia (OV-102) will enter OMDP for routine maintenance and structural inspection and installation of MEDS upgrade. In FY 2000, Discovery (OV-103) will enter OMDP for will be installed routine maintenance and structural inspection and installation of MEDS upgrade.

Expansion of the effort to replace the Orbiter's TACAN landing navigation system with the Global Positioning System (GPS) began in FY 1995. This expansion will include an increased interaction of the GPS receiver with the Orbiter backup flight software, and outfitting two more Orbiters with a GPS test receiver. A number of development flights will take place with increasing GPS capability while still utilizing TACAN navigation. The first flight of a complete GPS system is planned for 1999.

Propulsion Upgrades

The most complex components of the Space Shuttle Main Engine (SSME) are the high-pressure turbopumps. Engine system requirements result in pump discharge pressure levels from 6000 to 8000 psi and turbine inlet temperatures of 2000 Degrees F. In reviewing the most critical items on the SSME that could result in a catastrophic failure, 14 of the top 25 are associated with the turbopumps. The current pumps' dependence on extensive inspection to assure safety of flight have made them difficult to produce and costly to maintain. The Alternate Turbopump Program (ATP) contract with Pratt & Whitney was signed in December 1986 and called for parallel development of both the High Pressure Oxidizer Turbopump (HPOTP) and the High Pressure Fuel Turbopump (HPFTP) to correct the shortcomings of the existing high pressure turbopumps. This objective is achieved by several methods including utilizing design, analytical, and manufacturing technology not available during development of the original components; application of lessons learned from the original SSME development program; and elimination of failure modes from the design. The program also used implementation of a build-to-print fabrication and assembly process; full inspection capability by design; and demonstrated design reliability through increased fleet leader testing to meet this objective. The turbopumps utilize precision castings, reducing the total number of welds in the pumps from 769 to 7. Turbine blades, bearings, and rotor stiffness are all improved through the use of new materials and manufacturing techniques. The SSME upgrades will expand existing safety margins and reduce operational costs. HPFTP production and assembly should be complete in FY 2000.

The SSME Powerhead is the structural backbone of the engine. The Phase II+ Powerhead will reduce the number of welds, improving producibility and reliability. The last Phase II+ Powerhead is expected to be delivered in FY 2000.

The heat exchanger uses the hot turbine discharge gases to convert liquid oxygen in a thin walled coil to gaseous oxygen for pressurization of the external oxygen tank. The current heat exchanger coil has seven welds exposed to the hot gas environment. A small leak in one of these welds would result in catastrophic failure. The new Single Coil Heat Exchanger eliminated all seven critical welds and tripled the wall thickness.

The Large Throat Main Combustion Chamber (LTMCC) first flight was on STS-89 (January 1998) and will result in lower pressures and temperatures throughout the engine system thereby increasing the overall Space Shuttle system flight safety and reliability. The wider throat area accommodates additional cooling channels. Consequently, hot gas wall temperatures are significantly reduced increasing chamber life. The LTMCC design also incorporates new fabrication techniques to reduce the number of critical welds and improve the LTMCC production and assembly.

The development and production of the powerhead, heat exchanger and LTMCC are all being performed under contract with the Rocketdyne division of the Boeing North American Corporation.

The "block" change concept for incorporating changes into the main engine was introduced and baselined during FY 1994. The Phase II+ Powerhead, the Single Coil Heat Exchanger and the new high-pressure oxidizer turbopump comprise Block I. This change was introduced and flown for the first time in July 1995. The Block II engine is scheduled to be flown in FY 2000 and incorporates the alternate high-pressure fuel turbopump with the Block IIA design. The end result of these engine improvements is an increase in the overall engine durability, reliability and safety margin, and producibility. This is consistent with NASA's goals of decreasing failure probability and reducing Space Shuttle costs.

Increased safety margins and launch reliability on the Space Shuttle will also be realized through the implementation of new sensors (temperature, pressure and flow) for use in the SSME. SSME history has shown that the engine is more reliable than the instrumentation system; however, a transducer failure could result in a flight scrub or on-pad abort, failure to detect an engine fault, or an in-flight abort. Sensor upgrade development activities have been completed and will be essential to improving the reliability of the Space Shuttle's launch capability.

The Solid Rocket Booster also received several upgrades designed to reduce the expense of recovering and refurbishing the boosters. Those upgrades include a saltwater activated mechanism to release the parachutes (full implementation STS-95), improvements to the parachutes themselves, and a modification to the aft skirt brackets.

The SLWT program is a result of NASA's desire to enhance the payload capability of the Space Shuttle System to support the Space Station Program. The SLWT completed final assembly and proof testing in FY 1998 and the first SLWT was successfully flown on STS-91 (May 1998).

Flight Operations and Launch Site Equipment Upgrades

These upgrades support pre-launch and post-launch processing of the Orbiter fleet. Key projects funded in Launch Site Equipment address equipment obsolescence and enhance efficiency. Examples include: replacement of the hydraulic pumping units that provide power to Orbiter flight systems during ground processing; replacement of the 16-year old ground cooling units that support all Orbiter power-on testing; replacement of the test set for the KU-band radar; communications and instrumentation equipment modernization projects.

A new Checkout and Launch Control System (CLCS) was approved for development at KSC in FY 1997. The CLCS will upgrade the Shuttle launch control room systems with state-of-the-art commercial equipment and software in a phased manner to allow the existing flight schedule to be maintained. The CLCS will reduce operations and maintenance costs associated with the launch control room by as much as 50%, and will provide the building blocks to support future vehicle control system requirements. The "Thor" and "Atlas" phases were completed in FY 1998. During these phases, the initial applications for the Orbiter Processing Facility were developed, the math models were validated, Shuttle Avionics Integration Lab interfaces were established, and hardware testing was done. The Titan and Scout phases of CLCS are planned for FY 1999 during which Orbiter automated power-up will be developed, peripheral locations will be upgraded, and selected vertical testing will be done. In FY 2000, the Delta and Saturn phases will be accomplished which includes completion of all launch application development, completion of software certification and validation, and a complete integrated flow demonstration. Since the FY 1999 Budget, software independent validation and verification (IV&V) performed by Ames Research Center was also added to this project. By the end of FY 2000, Operations Control Room-1 will be fully operation, followed by certification in FY 2001. The first Shuttle launch using the CLCS is scheduled for FY 2001 with full implementation to be completed one year later.

The Hardware Interface Modules (HIM), which are electrical command distribution systems that support the launch processing system (LPS) at KSC, are over 25 years old and have experienced an increased failure rate and higher cost of repair over the past several years. The HIM upgrade replaces all chassis and cards with state-of-the-art "off the shelf" hardware to improve system reliability and maintainability. Production and installation will be completed in FY 1999.

A cable plant upgrade at KSC replaces the miles of cables that support a wide variety of Space Shuttle facilities. Many of these cables were installed in the 1960s and are suffering from corrosion and increasing failure rates. Replacement will reduce the potential for disruption to critical Space Shuttle operations as well as have a direct maintenance benefit. This activity will reduce the possibility of launch delays; increase communication system spares availability, and enhances the reliability of data, instrumentation, voice, and video communications. This upgrade will replace the wide-band distribution system and the lead/antimony sheath cables with fiber optics and plastic sheath, gel-filled cable. In addition, many field terminals will be replaced or upgraded. The upgrade should be complete in late FY 1998.

Modernization of the Operational Television System (OTV) is based upon a phased engineering design and implementation strategy, which should enhance and automate the visual surveillance capability at KSC. A key element of the plan includes the design of a camera control system beginning in FY 1996 through FY 2000 which allow the installation of new digital video cameras and their associated elements with minimal impact to operations. Other key elements of the design approach, beginning in FY 1997 are the phased transition to a high bandwidth digital switch, switched digital recording, integrated monitoring stations and a high priority subset of CCD cameras, utilizing a unified control over the entire television environment. Continual effort over the life span of the project, FY 1995 to FY 2004, to phase out existing tube cameras with new CCD cameras, provide functional camera station control and record capability to the new OCR's, sustain existing firing room support, and replace obsolete switching and recording hardware.

The Complex Control System (CCS) is used to monitor and control processing and institutional facilities systems at KSC. The obsolescence of the current CCS makes it difficult and costly to incorporate new measurements and control points as new facilities are build or existing ones are upgraded. CCS infrastructure conversion is scheduled for completion in FY 2001.

Radio Frequency (RF) communications modernization replaces the existing KSC radio communications system with a combination of digital and conventional mobile, portable and fixed stations, and associated off-the-shelf equipment. RF modernization is scheduled for completion in FY 2001.

Funds for other activities include implementing required modifications and upgrades on the T-38 aircraft used for space flight readiness training, capability improvements for weather prediction, and enhancements on information handling to improve system monitoring, notably for anomaly tracking.

Construction of Facilities (CoF)

FY 1998 CoF provided for improvements for facilities at KSC and MAF. At MAF, this project is Phase II of IV to rehabilitate the 480-volt electrical distribution system that is critical to the manufacturing of the external tank. At KSC, one project was restoring the walls and ceiling that provides a controlled environment to perform pre-flight services of Space Shuttle hardware at Pad A/LC-39 Payload Change-Out Room (PCR). The other project at KSC was to restore the concrete surfaces and slope of Pad A/LC-39 structure.

FY 1999 CoF funding will provide for improvements for facilities at KSC and MAF. At KSC, there are two projects which are both at Launch Complex Pad A - the restoration of the Fixed Support Structure Elevator System and the repair of the fire resistant surface of the Main and SRB flame deflector, repair/replacement of damaged and corroded structural members, and repair/replacement of bricks in the Flame Trench wall. At MAF, there are two projects, Phase III of IV for the rehabilitation of the 480-volt electrical distribution system and Repair Cell E Common solution return and lining. For additional details on these projects, please refer to the Mission Support - Construction of Facilities budget.

FY 2000 CoF funding will provide for improvements for facilities at KSC, MAF and SSC. At KSC, there are two projects at Launch Complex Pad B - the restoration of the Pad B concrete surfaces and slope and the restoration of the walls and ceiling that provide a controlled environment to perform pre-flight services of Space Shuttle hardware at Pad B/LC-39 Payload Change-out Room (PCR). A third project at KSC is the refurbishment of the Convoy Operations capability at the SLF. At MAF, the rehabilitation of the 480-volt electrical distribution system will be completed with the funding of Phase IV of IV. The SSC project will be Phase I of the rehabilitation of the A-2 Test Stand used for Space Shuttle Main Engine testing.

BASIS OF FY 2000 FUNDING REQUIREMENT

SHUTTLE OPERATIONS

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Orbiter and integration	507,900	608,000	709,400
Propulsion	1,021,800	1,051,200	1,133,200
[External tank]	[336,000]	[358,600]	[359,200]
[Space shuttle main engine]	[173,400]	[196,600]	[218,000]
[Reusable solid rocket motor]	[360,200]	[344,000]	[421,200]
[Solid rocket booster]	[152,200]	[152,000]	[134,800]
Mission and launch operations	814,700	767,500	704,800
Total	2,344,400	2,426,700	2,547,400

GENERAL

Space Shuttle operations requirements are met through a combination of funds received from appropriations and reimbursements received from customers whose payloads are manifested on the Space Shuttle. The reimbursements are applied consistent with the receipt of funds and mission lead times and is subject to revision as changes to the manifest occur. The FY 1998 standard services reimbursements totaled $11.9 million. The FY 1999 reimbursements are assumed to be $35.9 million, and FY 2000 reimbursements are assumed to be $27.4 million (the majority of FY 1999 and FY 2000 reimbursements are due to the Shuttle Radar Topography Mission). These standard services reimbursements offset the total budget for the Space Shuttle, and have been assumed in the NASA direct funding requirements identified above for the FY 2000 budget request.

The Space Shuttle operations budget includes sustaining engineering, hardware and software production, logistics, flight and ground operations, and flight crew operations for all elements while continuing to pursue environmentally necessary operations and manufacturing improvements. The single, prime contract is the Space Flight Operations Contract (SFOC) held by United Space Alliance comprising one-half of the Operations budget. As development items are completed, additional effort will be transitioned into SFOC.

Increases from FY 1998 to FY 1999 and FY2000 are caused by a number of factors, including: a significant reduction in beginning of fiscal year balances of uncosted prior year budget authority in FY 1998; understatement of requirements in FY1999 due to anticipated reimbursement from the National Imagery and Mapping Agency (NIMA) for the launch of the Shuttle Radar Topography Mission (SRTM); and the reductions in both 1998 and 1999 due to deferral of launches into the future which were documented in the Operating Plans for those years.

Orbiter and Integration

The Orbiter project element consists of the following items and activities:

(1) Orbiter logistics: spares for the replenishment of Line Replacement Units (LRUs) and Shop Replacement Units (SRUs) along with the workforce required to support the program; procurement of liquid propellants and gases for launch and base support;
(2) Production of External Tank (ET) disconnect hardware;
(3) Flight crew equipment processing as well as flight crew equipment spares and maintenance, including hardware to support Space Shuttle extravehicular activity;
(4) The sustaining engineering associated with flight software;
(5) Various Orbiter support hardware items such as Pyrotechnic-Initiated Controllers (PICs), NASA Standard Initiators (NSI's), and overhauls and repairs associated with the Remote Manipulator System (RMS); and
(6) The sustaining engineering associated with the Orbiter vehicles.

The major contractors for these Orbiter activities are United Space Alliance for operations; and Hamilton Standard for extravehicular mobility unit (EMU) operations.

Other support requirements are also provided for in this budget, including tasks that support flight software development and verification. The software activities include development, formulation, and verification of the guidance, targeting, and navigation systems software in the Orbiter. The Flight Software Contract with Lockheed Martin transitioned into the Phase II of the SFOC in FY 1998.

System integration includes those elements managed by the Space Shuttle Program Office at the Johnson Space Center (JSC) and conducted primarily by United Space Alliance, including payload integration into the Space Shuttle and systems integration of the flight hardware elements through all phases of flight. Payload integration provides for the engineering analysis needed to ensure that various payloads can be assembled and integrated to form a viable and safe cargo for each Space Shuttle mission. Systems integration includes the necessary mechanical, aerodynamic, and avionics engineering tasks to ensure that the launch vehicle can be safely launched, fly a safe ascent trajectory, achieve planned performance, and descend to a safe landing. In addition, funding is provided for multi-program support at JSC.

Propulsion

Lockheed Martin Corporation produces external Tanks in the Government-Owned/Contractor-Operated (GOCO) facility near New Orleans, LA. This activity involves the following:

(1) Procurement of materials and components from vendors;
(2) Engineering and manufacturing personnel and necessary environmental manufacturing improvements;
(3) Support personnel and other costs to operate the GOCO facility; and

(4) Sustaining engineering for flight support and anomaly resolution.

The program began delivering Super Lightweight Tanks to KSC in support of the performance enhancement goal required by the Space Station in FY 1998. All recurring costs associated with the Super Lightweight Tank are included in this account. Non-recurring activities were complete in 1998, and costs were accounted for in the Safety and Performance Upgrades budget. The External Tank contract is scheduled to be transitioned into Phase II SFOC in FY 2000.

The Space Shuttle Main Engine (SSME) operations budget provides for overhaul and repair of main engine components, procurement of main engine spare parts, and main engine flight support and anomaly resolution. In addition, this budget includes funding to the Department of Defense for Defense Contract Management Command (DCMC) support in the quality assurance and inspection of Space Shuttle hardware; and funds for transportation and logistics costs in support of SSME flight operations. Rocketdyne, a division of Boeing North American Corporation, provides the bulk of the engine components for flight as well as sustaining engineering, integration, and processing of the SSME for flight.

USA is the prime contractor on the Solid Rocket Booster (SRB) project and conducts SRB retrieval, refurbishment and processing at KSC. In FY 1998, the SRB contract was the first major element transitioned into Phase II SFOC. The Solid Rocket Booster (SRB) project supports:

(1) Procurement of hardware and materials needed to support the flight schedule;
(2) Work at various locations throughout the country for the repair of flown components;
(3) Workforce at the prime contractor facility for integration of both used and new components into a forward and an aft assembly; and
(4) Sustaining engineering for flight support.

Thiokol of Brigham City, Utah is the prime contractor for the Reusable Solid Rocket Motor (RSRM) project that includes:

(1) Purchase of solid rocket propellant and other materials to manufacture motors and nozzle elements.
(2) Workforce to repair and refurbish flown rocket case segments, assemble individual case segments into casting segments and other production operations including shipment to the launch site;
(3) Engineering personnel required for flight support and anomaly resolution; and
(4) New hardware to support the flight schedule required as a result of attrition.

Mission and Launch Operations

Launch and Landing Operations provides the workforce and materials to process and prepare the Space Shuttle flight hardware elements for launch as they flow through the processing facilities at the Kennedy Space Center (KSC). The primary contractor is United Space Alliance. This category also funds standard processing and preparation of payloads as they are integrated into the Orbiter. It also provides for support to landing operations at KSC (primary), Dryden Flight Research Center (back-up) and contingency sites.

Operation of the launch and landing facilities and equipment at KSC involves refurbishing the Orbiter, stacking and mating of the flight hardware elements into a launch vehicle configuration, verifying the launch configuration, and operating the launch processing system prior to lift-off. Launch operations also provides for booster retrieval operations, configuration control, logistics, transportation, inventory management, and other launch support services. This element also provides funds for:

(1) Maintaining and repairing the central data subsystem, which supports Space Shuttle processing as an on-line element of the launch processing system;
(2) Space Shuttle-related data management functions such as work control and test procedures;
(3) Purchase of equipment, supplies and services: and
(4) Operations support functions including propellant processing, life support systems maintenance, railroad maintenance, pressure vessel certification, Space Shuttle landing facility upkeep, range support, and equipment modifications.

Mission and Crew Operations include a wide variety of pre-flight planning, crew training, operations control activities, flight crew operations support, aircraft maintenance and operations, and life sciences operations support. The primary contractor is USA. The planning activities range from the development of operational concepts and techniques to the creation of detailed systems operational procedures and checklists. Tasks include:

(1) Flight planning:
(2) Preparing systems and software handbooks;
(3) Defining flight rules;
(4) Creating detailed crew activity plans and procedures;
(5) Updating network system requirements for each flight;
(6) Contributing to planning for the selection and operation of Space Shuttle payloads; and
(7) Preparation and plans for International Space Station assembly.

Also included are the Mission Control Center (MCC), Integrated Training Facility (ITF), Integrated Planning System (IPS), and the Software Production Facility (SPF). Except for the SPF (Space Shuttle only), these facilities integrate the mission operations requirements for both the Space Shuttle and International Space Station. Flight planning encompasses flight design, flight analysis, and software activities. Both conceptual and operational flight profiles are designed for each flight, and the designers also help to develop crew training simulations and flight techniques. In addition, the flight designers must develop unique, flight-dependent data for each mission. The data are stored in erasable memories located in the Orbiter, ITF Space Shuttle mission simulators, and MCC computer systems. Mission operations funding also provides for the maintenance and operation of critical mission support facilities including the MCC, ITF. IPS and SPF. Finally, Mission and Crew Operations include maintenance and operations of aircraft needed for flight training and crew proficiency requirements.

PROGRAM GOALS

The goal of Space Shuttle Operations is to provide safe, reliable, and effective access to space. This budget is based on an average of seven flights annually with a surge capability to nine flights and remains essentially unchanged from previous years. Although FY 1998 had only four flights, and six flights are planned for FY 1999, an eight-flight year is planned for FY 2000 that will include the third Hubble Space Telescope servicing mission. FY 2001 is a nine-flight year with the X-38 Flight Demonstration, and a research mission which will include the Triana spacecraft. The flight rate is anticipated to continue at eight per year through FY 2003 and seven flights in FY 2004 without any significant increase in this budget. This represents a no change in the total number of flights during this time period from previous submissions. This manifest supports the Nation's science and technology objectives through scheduled Spacehab and other science missions, and commencement of assembly of the International Space Station.

STRATEGY FOR ACHIEVING GOALS

The Space Shuttle program is aggressively continuing to reduce the cost of operations. Since FY 1992, cost reduction efforts have been successful in identifying and implementing program efficiencies and specific content reductions. Space Shuttle project offices and contractors have been challenged to meet reduced budget targets.

United Space Alliance (USA) was awarded the Space Flight Operations Contract (SFOC) on October 1, 1996. It includes a phased approach to consolidating operations into a single prime contract for operational activities. The first phase began in late 1996 with 12 operational and facility contracts being consolidated from the majority of the effort previously conducted by Lockheed Martin and Boeing North American (the two corporations which comprise the USA joint venture). The second phase will add other operations work to the contract after the contractor has had an appropriate amount of time to evolve into its more responsible role in phase I. Transition will take another 1-2 years and employ approximately 7300 equivalent persons at steady state. All transitions will be completed in FY 2001. The reasons for this phased approach are:

1. The ongoing major development projects will be completed.
2. The transition to the prime can occur at a more measured pace.

The roles and missions of the contractor and government under this contract have been defined to ensure program priorities are maintained and goals are achieved. The SFOC contractor is responsible for flight, ground, and mission operations of the Space Shuttle. The accountability of its actions and those of its subcontractors will be evaluated and incentivized through the use of a combined award/incentive fee structure of the performance-based contract. NASA, as owner of assets, customer of operations services, and director of launch/flight operations, is responsible for (a) surveillance and audit to ensure compliance with SFOC requirements, and (b) internal NASA functions. Further, NASA retains chairmanship of control boards and forums responsible for acceptance/rejection/waiver of Government requirements while the SFOC contractor is responsible for requirement implementation. The SFOC contractor is required to document and maintain process/controls necessary to ensure compliance with contract requirements and to sign a certification of flight readiness (CoFR) to that effect for each flight.

SCHEDULE AND OUTPUTS

Since the Space Shuttle program has both an operational and development component, performance measures related to the Space Shuttle program reflect a number of different activities ranging from missions planned and time on-orbit in Shuttle Operations, to development milestones planned for the Safety and Performance Upgrades program. The following sets of diverse metrics can be utilized to assess program performance.

	FY 1998		FY 1999		FY 2000
Operations Metrics	Plan	Actual	Plan	Revised	Plan
Number of Space Shuttle Flights	6	4	8	6	8
Shuttle Operations Workforce (Prime Contractor (equivalent personnel))	16,023	16,519	15,550	16,023	15,550
Space Shuttle Processing Overtime Required	3%	3%	3%	3%	3%
Number of Days On-orbit	68	50	90	59	80
Number of Primary Payloads Flown	8	5	9	6	8

Space Shuttle Missions and Primary Payloads

FY 1998		Plan	Actual/Revised
STS-87/Columbia	Microgravity Payload (USMP-04)/Spartan 201-04	November 1997	November 1997
STS-89/Endeavour	Russian Space Station Mir (Mir-8)/Spacehab	January 1998	January 1998
STS-90/Columbia	Neurolab	April 1998	April 1998
STS-91/Discovery	Russian Space Station Mir (Mir-9)/Spacehab	May 1998	June 1998
FY 1999		**Plan**	**Actual/Revised**
STS-95/Discovery	Hubble Orbital System Test (HOST)/Spacehab	October 1998	October 1998
STS-88/Endeavour	Space Station #1 (Node 1) (ISS-01-2A)	July 1998	December 1998
STS-93/Columbia	AXAF	August 1998	3rd Qtr FY 1999
STS-96/Discovery	Space Station #2 Spacehab Cargo Module (ISS-02-2A.1	December 1998	3rd Qtr FY 1999
STS-101/Atlantis	Space Station #2A Spacehab Cargo Module (ISS-02-2A.2)	January 1999	4th Qtr FY 1999
STS-99/Endeavour	Shuttle Radar Topography Mission (SRTM)	September 1999	4th Qtr FY 1999
FY 2000		**Plan**	**Revised**
STS-92/Discovery	Space Station #3 (ITS-Z1) (ISS-03-3A)	October 1999	1st Qtr FY 2000
STS-97/Atlantis	Space Station #4 (PV Module) (ISS-04-4A)	April 1999	1st Qtr FY 2000
STS-98/Endeavour	Space Station #5 (US Lab) (ISS-05-5A)	May 1999	2nd Qtr FY 2000
STS-102/Discovery	Space Station #6 (MPLM) (ISS-06-5A.1)	June 1999	2nd Qtr FY 2000
STS-100/Atlantis	Space Station #7 (MPLM-1) (ISS-07-6A)	August 1999	3rd Qtr FY 2000
STS-103/Endeavour	Space Station #8 (Airlock) (ISS-08-7A)	July 2000	4th Qtr FY 2000
STS-104/Columbia	Hubble Space Telescope (HST)	August 2000	4th Qtr FY 2000
STS-105/Atlantis	Space Station #9 (MPLM-2) (ISS-09-7A.1)	August 2000	4th Qtr FY 2000

The Space Shuttle program currently provides launch support for space science missions accommodating universities and industry as a space laboratory and technology research vehicle. Beginning in FY 1999, its primary mission will be to support the on-orbit assembly and operations of the International Space Station. The Shuttle is also the only U.S. vehicle that provides human transportation to and from orbit. In FY 1998, 26 crew members flew approximately 574 days, including time spent by an American astronaut aboard Mir. In FY 1999, 38 crew members are planned to fly approximately 372 days with the first docking of the International Space Station planned on STS-96. This will be followed by approximately 56 crew members flying 840 crew days in FY 2000, including time spent by Americans aboard the International Space Station.

To supplement the network of management reviews and government oversight functions, NASA continues to seek specific objective measurements of overall performance of the Space Shuttle program. In order to permit rapid review by the program managers, the Shuttle program has devised a series of "stoplight" metrics. The metrics are devised whereby certain program aspects are measured against established limits or program parameters and then translated into the appropriate green, yellow or red indicators. Among the metrics displayed in this manner are in-flight anomalies, monthly cost rate, Shuttle processing monthly mishaps, Orbiter systems and line replaceable unit (LRU) problem reports, Shuttle processing contract overtime percentage, and KSC quality surveillance error rate. The Shuttle program also tracks its launch history, monitoring the number of liftoff attempts per mission, and characterizing any delays or scrubs as to technical, weather or operational-related reasons.

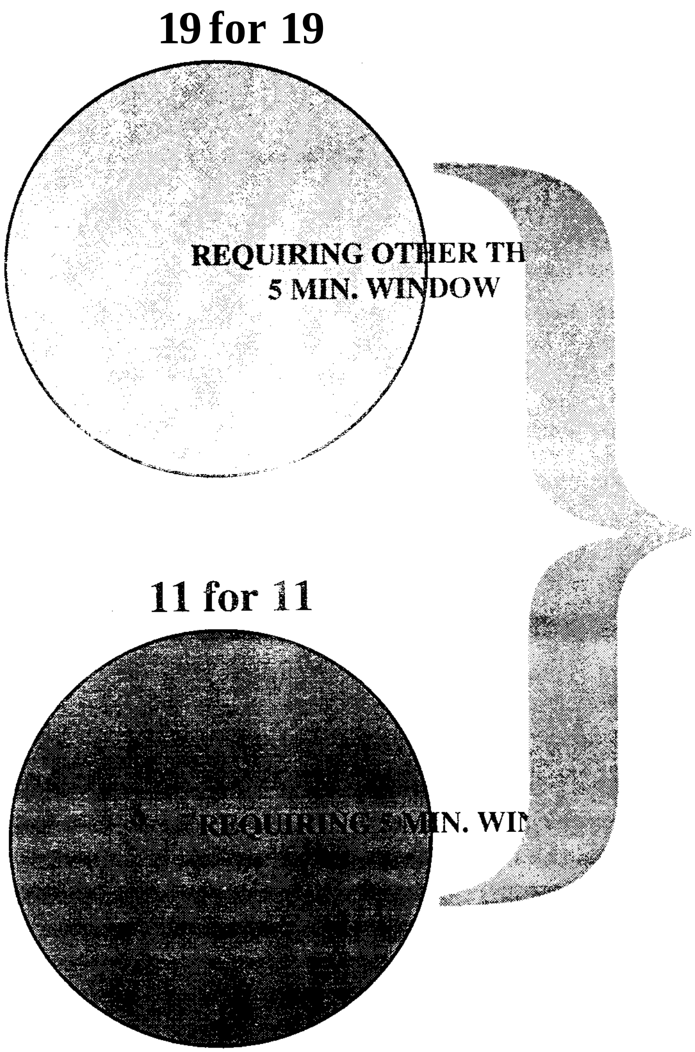
ACCOMPLISHMENTS AND PLANS

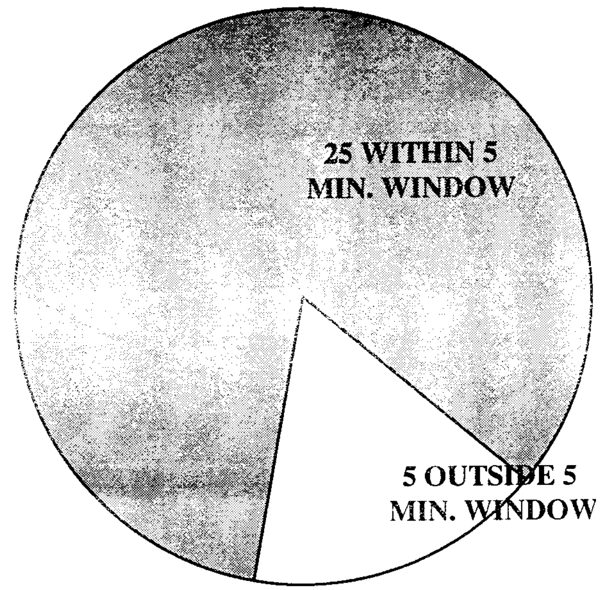
In FY 1998, the Space Shuttle launched four flights successfully. Flights included the last Spacelab mission (Neurolab), two re-supply flights to the Russian Space Station Mir, and the United States Microgravity Payload (USMP) with a Spartan payload. The Alpha Magnetic Spectrometer (AMS) investigation was also conducted on the second Mir mission.

Six flights are manifested for FY 1999. The first mission included a Spartan payload, the Hubble Orbital Systems Test (HOST) platform, a series of experiments by the National Institute on Aging, and the return to space of Senator John Glenn. The Space Shuttle will support the International Space Station with three flights this year, including the initial assembly flight. The Shuttle will also fly the Shuttle Radar Topography Mission (SRTM), a joint DOD/NASA payload to study the earth. Finally, the Space Shuttle plans to deploy the last of the "Great Observatories" when it launches the Advanced X-Ray Astrophysics Facility (AXAF).

Eight flights will be flown during FY 2000, including seven International Space Station assembly flights and the third Hubble Space Telescope servicing mission.

30 for 30 LAUNCHES MEETING OUR COMMITMENT
(STS-64 thru STS-88)





STS-64 : Weather in the RTLS area
STS-72 : Computer communication problem
STS-83 : Late tanking & hatch closeout cover
STS-94: Weather at KSC
STS-95: Intruder aircraft

12/4/98

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT **PAYLOAD UTILIZATION AND OPERATIONS**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Spacelab	9,100	--	--	LVPO 2-3
Payload processing and support	46,700	39,200	49,300	LVPO 2-5
Expendable launch vehicle support	--	31,500	28,600	LVPO 2-8
Advanced projects	46,700	10,000	6,000	LVPO 2-10
Engineering and technical base	102,900	96,300	85,200	LVPO 2-14
Total	205,400	177,000	169,100	

Distribution of Program Amount by Installation

	FY 1998	FY 1999	FY 2000
Johnson Space Center	83,209	35,500	37,800
Kennedy Space Center	52,541	67,600	79,000
Marshall Space Flight Center	53,450	49,600	41,500
Stennis Space Center	1,500	1,500	1,600
Ames Research Center	500	--	--
Langley Research Center	132	--	--
Glenn Research Center	750	--	--
Goddard Space Flight Center	9,800	12,800	8,200
Headquarters	3,518	10,000	1,000
Total	205,400	177,000	169,100

PROGRAM GOALS

There are several goals in the Payload Utilization and Operations budget. They range from supporting the processing and flight of Space Shuttle payloads and NASA payloads launched from Expendable Launch Vehicles (ELV), to ensuring maximum return on the research investment, to reducing operations costs, to continuing to implement flight and ground systems improvements, and to supporting strategic investments in advanced technology needed to meet future requirements.

STRATEGY FOR ACHIEVING GOALS

The principal areas of activity in the Payload Utilization and Operations program are: 1) provide safe and efficient payload preparations and launch and landing services while reducing costs of Space Shuttle-related services; 2) provide mission planning, integration and processing for science application missions utilizing -the Multiple-Purpose Experiment Support Structures (MPESS) and payload pallets; 3) within Advanced Projects, identify and develop advanced technology to support Shuttle, International Space Station (ISS) and future Human Exploration and Development of Space programs to improve safety and reduce costs, promote space commercialization and technology transfer, and manage the agency's Orbital Debris program; and 4) within Engineering and Technical Base (ETB), empower a core workforce to operate Human Space Flight laboratories, technical facilities, and test beds, and stimulate science and technical competence in the United States. The Payload Utilization and Operations budget reflects a commitment to meet a wide array of programs. This includes Space Shuttle and science missions, flight hardware development and integration, space flight safety projects, and maintenance of an institutional base from which to perform NASA programs at reduced cost through re-engineering, consolidation and operational efficiency processes. Beginning in FY 1999, Expendable Launch Vehicle (ELV) mission support was consolidated and transferred from Mission to Planet Earth and Space Science to provide more focused and efficient management of launch services to be located at the Kennedy Space Center and Cape Canaveral Air Force Base in Florida. The highly successful Spacelab program has been completed.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACELAB

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Spacelab	9,100	--	--

PROGRAM GOALS

The highly successful Spacelab program has been completed.

STRATEGY FOR ACHIEVING GOALS

The Spacelab program has been completed. Spacelab hardware has been transferred to the National Air and Space Museum, to other NASA programs, and to the European Space Agency (on loan). The Program has properly disposed of any residual hardware. The last Spacelab flight (Neurolab) was launched in April 1998, with the expectation that the more permanent science laboratory flown by the International Space Station (ISS) would soon be available. In FY 1998, Spacelab operations funding for GAS, Hitchhiker payloads and the FSS, as well as the Pallets and Multi-Purpose Experiment Support Structures (MPESS) was transferred to the Payload Processing and Support budget.

SCHEDULE AND OUTPUTS

Spacelab Missions	Plan	Actual
United States Microgravity Payload (USMP-4)	October 1997	November 1997
Space Life Sciences Laboratory-4 (Neurolab)	March 1998	April 1998

	FY 1998		FY 1999		FY 2000
Flight Hardware Utilized	Plan	Actual	Plan	Revised	Plan
Long Module	1	1	--	--	--
Multi-Purpose Experiment Support Structures (MPESS)	1	1	--	--	--
Hitchhiker Experiments	8	7	--	--	--
Get Away Special Payloads	7+TBD	14	--	--	--
Contractor Workforce					
KSC (Boeing)	78	93	--	--	--
MSFC (Boeing)	70	78	--	--	--

ACCOMPLISHMENTS AND PLANS

In FY 1998, the Spacelab program supported the requirements and provided the infrastructure to fly the United States Microgravity Payload (USMP-4) and Neurolab missions. Because the Spacelab program was terminated in FY 1998, the Hitchhiker, GAS, and FSS programs were transferred to the Payload Carriers and Support program. Following the Neurolab mission, the final Spacelab program phase-down began, with the transfer of one module to the National Air and Space Museum, the transfer of considerable program hardware to other NASA programs, and disposal of residual hardware.

BASIS OF FY 2000 FUNDING REQUIREMENT

PAYLOAD PROCESSING AND SUPPORT

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Payload processing and support	46,700	39,200	49,300

PROGRAM GOALS

The primary goal for payload processing and support is to safely and efficiently assemble, test, checkout, service, and integrate a wide variety of spacecraft and space experiments that will fly on the Space Shuttle.

STRATEGY FOR ACHIEVING GOALS

The payload processing and support program provides the technical expertise, facilities and capabilities necessary to perform payload buildup; test and checkout; integration and servicing of multiple payloads; transportation to the Space Shuttle; and integration and installation into the Space Shuttle. Included in this program are operational efficiencies gained to date, as well as additional anticipated efficiencies to reduce cost and improve customer satisfaction. Efficiencies already in place have reduced processing time and error rate. Due to the termination of the Spacelab program in FY 1998, the Hitchhiker, Get Away Special (GAS) and Flight Support System (FSS) program became part of the Payload Processing and Support program in FY 1998.

Payload processing and support also funds smaller secondary payloads like the Get-Away Specials (GAS) and Hitchhiker payloads. The GAS payloads are research experiments that are flown in standard canisters, which can fit either on the side wall of the cargo bay or across the bay on the GAS bridge. They are the simplest of the small payloads with limited electrical and mechanical interfaces. Approximately 155 GAS payloads have been flown. The Hitchhiker payloads are the more complex of the smaller payloads, and provide opportunities for larger, more sophisticated experiments. The Hitchhiker system employs two carrier configurations: (1) a configuration on the orbiter payload bay side wall and (2) a configuration across the payload bay using a multi-purpose experiment support structure (MPESS). During the mission, the Hitchhiker payloads can be controlled and data can be received using the aft flight deck computer/standard switch panels or from the ground through the payload operations control center (POCC).

Payload analytical integration is the responsibility of the Payload Projects Office at the Marshall Space Flight Center (MSFC), and supported by a contract with Boeing. Physical payload integration and processing is the responsibility of the Payload Management and Operations Office at the KSC, and also supported by a contract with Boeing.

Another item funded in payload processing and support is the Flight Support System (FSS). The FSS consists of three standard cradles with berthing and pointing systems along with avionics. It is used for on-orbit maintenance, repair, and retrieval of spacecraft. The FSS is used on the Hubble Space Telescope (HST) repair/revisit missions.

SCHEDULE AND OUTPUTS

Missions Supported	FY 1998 Plan	FY 1998 Actual	FY 1999 Plan	FY 1999 Revised	FY 2000 Plan
Space Shuttle Missions	6	4	8	6	8
Spacelab Payloads	1	1	--	--	--
Hitchhiker Experiments, includes CAP/SEM/HH Jr.	6+TBD	7	4+TBD	13	4-6
Get-Away Special Payloads	7+TBD	14	TBD	5	10-20
Spacehab/Mir Missions	2	2	1	2	--
Other Major Payloads	4	3	--	8	8
Other Secondary Payloads	21	22	TBD	34	0
Multi-Purpose Experiment Support Structure (MPESS)	--	1	--	--	--
Pallets	--	--	--	2	8
Expendable Launch Services	a	5	8	13	4
Number of Payload Facilities Operating at KSC	6	6	6	6	6
KSC Payload Ground Operations (PGOC) Workforce	366	366	312	341	334

ACCOMPLISHMENTS AND PLANS

The Hitchhiker, *GAS,* and FSS programs, as well as the Pallets and Multi-Purpose Experiment Support Structures (MPESS) from the Spacelab program, were transferred to the Payload Carriers and Support program in FY 1998.

The Payload Carriers and Support provided the payload carrier and integration activities for the USMP-4 mission. Launch and landing payload support activities encompass four Space Shuttle missions and payload processing support activities and facilities for nine manifested major payloads, including the last two Spacehab missions to Mir and one ISS flight (first element launch). Over 25 manifested major and secondary payloads were also supported. Reimbursable funds of $719,000 were received in FY 1998 to cover processing costs for GAS and Hitchhiker payloads.

In FY 1999, Payload Carriers and Support will provide the payload carriers and associated avionics for the Shuttle Radar Topography Mission (SRTM) and the HST Orbital Systems Test (HOST). Payload integration activities will also be provided for SRTM. Launch and landing payload support activities will be provided for six Space Shuttle missions, including the SRTM and a science transition mission for Spacehab (STS-95). Payload processing support activities and facilities will be provided for ten manifested major payloads. including four ISS flights. A number of secondary payloads will also be supported, including **4** payloads to be ejected from Hitchhiker carriers. Reimbursable funds of $759,000 are expected to be received in FY 1999 to cover processing costs of GAS and Hitchhiker payloads.

In FY 2000, Payload Carriers and Support will provide pallets for Hubble Space Telescope (HST) Servicing Mission 3 and for three ISS assembly flights. Launch and landing payload support activities will be provided for eight Space Shuttle missions, encompassing payload processing support activities and facilities for 14 major payloads, including seven ISS assembly and utilization flights. A number of secondary payloads will also be supported. One of the FSS cradles will support the spacecraft and rocket motor for the Triana mission, scheduled to launch in FY 2001. Reimbursable funds of $786,000 are expected to be received in FY 2000 to cover processing costs for GAS and Hitchhiker payloads.

BASIS OF FY 2000 FUNDING REQUIREMENT

EXPENDABLE LAUNCH VEHICLE SUPPORT

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Expendable Launch Vehicle Support	--	31,500	28,600

PROGRAM GOALS

The goals of the Expendable Launch Vehicle (ELV) mission support program are to: (1) enhance probability of mission success and on-time cost effective launch services for NASA missions undertaken in support of NASA's strategic plan; (2) provide comprehensive advanced mission analysis and feasibility assessments for NASA payload customers; (3) increase efficiency in launch site operations and countdown management; and (4) provide low cost secondary payload opportunities.

STRATEGY FOR ACHIEVING GOALS

NASA has consolidated ELV management and acquisition of launch services at Kennedy Space Center (KSC). Effective in FY 1999, all funding for mission support will likewise be transitioned from the Office of Space Science and the Office of Mission to Planet Earth to the Office of Space Flight, consistent with assignment of responsibility for ELV management to OSF.

KSC is responsible for acquiring requisite launch services to meet all NASA requirements and for increasing the probability of mission success through focused technical insight of commercially provided launch services. A core team of civil servants located primarily at KSC performs technical management of this program supported by contractor personnel. KSC personnel are also resident at key launch sites, launch facilities and customer facilities. NASA personnel are resident at Vandenberg AFB in California where all launches into a polar orbit, such as those required by the Mission to Planet Earth Enterprise, are conducted. NASA resident office personnel are located in launch service contractor plants, specifically, the Lockheed Martin Corporation Atlas Centaur plant in Denver and the Boeing Corporation Delta plant in Huntington Beach, California. On-site customer offices are being established at the centers assigned program management responsibility for the majority of Space Science (JPL) and Mission to Planet Earth (GSFC) missions that require access to space via NASA-funded ELV services.

Advanced mission design/analysis and leading edge integration services are provided for the full range of NASA missions under consideration for launch on ELV's. Technical launch vehicle support is provided in the development and evaluation of spacecraft Announcement of Opportunities, to enable cost effective consideration of launch service options and technical compatibility. Early definition of vehicle requirements enables smooth transition to launch service and an excellent cost containment strategy.

Launch site operations and countdown management is being improved through the use of a consolidated launch team, efficient telemetry systems, and close partnership with the contractor and USAF to assure lowest cost launch complex operations.

NASA's ELV secondary payload program enables efficient use of excess vehicle performance on selected NASA, USAF and commercial missions through funding integration of small secondary payloads. The secondary payloads come from university research institutions and often international cooperatives which can afford the constraints of this unique option, which is to take advantage of available limited excess space and performance from a primary payload and accept it's launch schedule and orbit. NASA has developed a standard Delta secondary launch vehicle capability and has similar discussions under way with other US ELV providers.

SCHEDULE AND OUTPUTS

	FY 1998		FY 1999		FY 2000
Missions Supported	Plan	Actual	Plan	Revised	Plan
ELV Missions	8	4	11	13	8
Secondary Payloads	3	1	0	3	3

ACCOMPLISHMENTS AND PLANS

During FY 1998, eight ELV launches and one secondary ELV mission were planned. The Cassini mission was successfully launched on October 15, 1997 using an USAF-provided Titan IV Centaur launch vehicle. Two Pegasus launches, SNOE and TRACE, were launched along with one Titan II provided by the USAF; and the pathfinder activity was accomplished for first launch of an Atlas-Centaur from a new launch site at Vandenberg. NASA has worked closely with the USAF and Lockheed Martin Corporation, provider of the Atlas IIAS launch services, to conduct pathfinder operations at the newly constructed West Coast Atlas launch pad. KSC also ran the SELV II SEB which resulted in the award of multiple Small ELV launch services (SELV II) contracts early in FY 1999 to assure access to space for NASA small explorer (SMEX) and earth system science probes (ESSP) class of payloads.

Support for 13 missions, including EOS AM-1, Landsat-7, and four planetary missions are planned for launch in FY 1999 and integration and technical management of 24 payloads planned for launch in FY 2000 and FY 2001 are supported in this request along with mission analysis and studies in support of Flight Planning Board Activities.

The ELV Sustaining effort will support launch site maintenance and sustaining operations at Vandenberg AFB and Cape Canaveral Air Station, technical insight across all launch vehicle classes (Small, Med-Lite, Medium, & Intermediate), and flight of 1-2 secondary payloads a year. Support for launch, integration and technical management of 24 payloads planned for launch in FY2000 and FY 2001 are supported in this request along with mission analysis & studies in support of Flight Planning Board activities.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED PROJECTS

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Advanced projects	46,700	10,000	6,000

PROGRAM GOALS

In FY 1998, NASA reallocated most of the Advanced Projects funding to meet critical needs of the International Space Station (ISS), with the exception of the X-38 project which should be complete in FY 2000. Efforts have continued as a largely in-house activity to meet long-term Human Space Flight goals under the funding for the Engineering and Technical Base (ETB). These efforts will continue as reflected in the ETB section of the Launch Vehicles and Payloads Operations budget narrative.

STRATEGY FOR ACHIEVING GOALS

For safety reasons, a Crew Return Vehicle (CRV) is necessary for permanent human habitation of the International Space Station. The Russian Soyuz spacecraft will provide the crew-return vehicle capability while the three crewmembers are accommodated aboard the station. The U.S. is developing a CRV to meet crew return requirements when station capability grows beyond three crew memebrs. As an interim capability prior to the availability of the U.S. CRV, additional Soyuz vehicles could be used. The X-38 experimental vehicle program is specifically intended to demonstrate the technologies and processes required to produce a CRV in a "better, faster, cheaper" mode. Evaluations of the performance of the technologies of the X-38 systems are conducted through a series of ground, air, and space tests. The X-38 is based on the U.S. Air Force/Martin-Marietta X-24A lifting body research vehicle. Successful demonstration of the X-38 technologies is a precursor to the decision process to select a long-term CRV configuration for the International Space Station. Through cooperative arrangements that are under discussion with the European Space Agency, the DOD, and the Japanese Space Agency, NASA also seeks to identify opportunities for commonality among space vehicles being developed. An independent study was initiated in FY 1998 to assess the cost estimates and applicability of the X-38 design for the Space Station CRV. In addition, the study will assess options for a Crew Transfer Vehicle (CTV) and other options which meet the Space Station's crew rescue requirements. This study will augment the industry-led Future Launch studies described in the Aeronautics and Space Transportation Technology section. The decision on whether to start development of a crew return vehicle is planned for FY 2000, with a target of providing the first vehicle for deployment in FY 2004. The decision will be closely tied to progress on Space Station assembly and depend on X-38 progress, alternative design concepts, and the results of the Future Launch studies.

SCHEDULE AND OUTPUTS

The success of the Advanced Projects activities has been measured by the success of its projects. Over 100 projects have been supported in the past six years, most of which have been successful in delivering products that enhance the efficiency and reduce the cost of ground and flight operations. Many of the advanced technologies incorporated in the new integrated Shuttle/Station Mission Control Center were developed in this program. These technologies are contributing to a significant reduction of Office of

Space Flight mission operations costs. Modest investments in these activities will be continued under ETB.

In the Orbital Debris activity, accurate measurements have been made of the orbital debris environment. Models have been developed to predict the changes in the environment as a function of time. Utilizing these measurements, flight rules, operational procedures, and new orbital debris protection systems have been developed and/or modified to improve/enhance safety during Shuttle and Space Station operations. Space Station and Space Shuttle now provide financial support for this activity, as they are the programs directly benefiting from this effort.

The following events represent significant milestones in the successful completion of this program:

Advanced Space Systems

Orbital Debris Collector (ODC) Returned from Mir Plan: 4th Qtr FY 1997 Actual: 1st Qtr FY 1998	The ODC is an experiment to collect *in-situ* samples of the micro debris environment from the orbit of the International Space Station to understand the sources of this debris and thus enabling effective steps to mitigate it.
Students for the Exploration and Development of Space Satellite (SEDSAT) Launch Plan: 4th Qtr FY 1997 Actual: 3rd Qtr FY 1998	Deployment of SEDSAT as a DELTA II secondary payload. SEDSAT serves as an amateur radio relay system and collects multi-spectral remote sensing data. This deployment had been delayed because the payload was re-manifested from the Shuttle to a Delta expendable launch vehicle.

Telerobotics Research and Technology

Free-Flying Camera Robots for EVA Plan: 4th Qtr FY 1997 Actual: 1st Qtr FY 1998	Implement upgrades to the existing Supplemental Camera and Maneuvering Platform (SCAMP) system.

Advanced EVA Research and Development

Soft space suit configuration hardware delivery Plan: 2nd Qtr FY 1998 Actual: Defer	Delivery of new soft space suit for testing. Soft suits hold potential of being lighter weight and easier to stow. Deferred because of significant reductions in available funding.
Soft space suit configuration comparison test delivery Plan: 3rd Qtr FY 1998 Actual: Defer	Demonstrates the amount of mobility that can be incorporated into a soft suit configuration. Deferred because of significant reductions in available funding.

Radiator ready for test
Plan: 3rd Qtr FY 1998
Actual: Defer

Demonstrates on-orbit cooling using a radiator instead of water sublimation in the real thermal environment.
Deferred because of significant reductions in available funding.

X-38

Atmospheric Test Program
Plan: 4th Qtr FY 1997
Revised: 4th Qtr FY 1998

Five atmospheric test flights of Vehicles 131 and 132 conducted to demonstrate full lifting body control and parafoil control systems. This milestone has been delayed due to difficulties in parafoil testing.

Award contract for de-orbit module
Plan: 2nd Qtr FY 1998
Actual: 4th Qtr FY 1998

Purchase of de-orbit module for X-38 orbital flight test

CRV Formulation Study
Plan: 3rd Qtr FY 1998
Actual: 1st Qtr FY 1999

Initiate independent assessment regarding the cost and applicability of the X-38 design for the CRV.

Flight test for the third atmospheric vehicle
Plan: 4th Qtr FY 1999

Additional testing will be conducted to demonstrate full lifting body control, using the sub-scale vehicle with final shape.

Shuttle Space Flight Test for Vehicle 201
Plan: Under Review

ACCOMPLISHMENTS AND PLANS

The X-38 experimental vehicle program is specifically intended to demonstrate the technologies and processes required to produce a human-rated spacecraft such as a Crew Return Vehicle (CRV) in a "better, faster, cheaper" mode. A CRV is necessary for permanent human habitation of the International Space Station to ensure crew safety. The Russian Soyuz spacecraft will provide crew return vehicle capability during the 3-crew member stage, and could provide an interim capability during the six crew member stage, until the CRV becomes operational in 2004.

Evaluations of the performance of the technologies of the X-38 systems are conducted through a series of ground, air, and space flight tests. The first atmospheric flight test was conducted on March 12, 1998 as the X-38 test vehicle (Vehicle 131; 24 ft. scale vs. 30 ft scale for operational CRVs) was dropped from under the wing of a NASA B-52, deployed its parafoil parachute and completed a guided descent from 23,000 feet altitude to a nominal landing. Additional atmospheric flight tests are scheduled to continue over the next two years using three increasingly complex test vehicles. A second flight for V131 is planned for early FY 1999. The tests will culminate in the year 2000 with the deployment of an unpiloted space test vehicle from the Space Shuttle and a controlled descent to landing. A third atmospheric test vehicle in full operational scale will be added to the X-38 program for atmospheric flight-testing.

A second atmospheric flight test vehicle (V132) in 24-ft. scale will demonstrate a lifting body flight control system using Electro Mechanical Actuators (EMAs) and advanced control software technology. In 1999 V132 will begin a series of at least six flight tests at the Dryden Flight Research Facility. A third atmospheric test vehicle (V133) is a modified shape in operational 30-ft. scale. It is scheduled to undergo flight tests in 2000 with the primary goal of aerodynamic verification of shape modifications and control laws. The X-38 space flight test vehicle (V201) is also 30-ft. operational scale and is scheduled for launch on the Space Shuttle in late 2000 to demonstrate the full range of CRV flight operations, including space flight, reentry and parafoil landing test.

The decision on whether to start development of a crew return vehicle is planned for FY 2000, with a target of providing the first vehicle for deployment in FY 2004. The decision will be closely tied to progress on Space Station assembly and depend on X-38 progress, alternative design concepts, and the results of the Future Launch studies.

Advanced technology development projects will focus on innovative, high-leverage technologies that will enable the development of new capabilities to meet future human space flight needs. The program will continue trade studies and mission analysis for the human exploration and development of space, with planned updates to key planning documents. Technology development for advanced EVA capability will focus on development of improved soft goods, gloves, multi-bearing shoulder joints, and a modular Primary Life Support System. As previously noted, Advanced Projects, other than the X-38 program, are being continued as a modest, largely in-house activity with funding requested for the Engineering and Technical Base (ETB).

BASIS OF FY 2000 FUNDING REQUIREMENT

ENGINEERING AND TECHNICAL BASE

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Engineering and technical base	102,900	96,300	85,200

PROGRAM GOALS

The focus of the Engineering and Technical Base (ETB) is to support the institutional capability in the operation of space flight laboratories. technical facilities, and testbeds; to conduct independent safety, and reliability assessments: and to stimulate science and technical competence in the United States. ETB activities are carried out at the Johnson Space Center (JSC) including White Sands Test Facility (WSTF), Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), and Stennis Space Center (SSC). ETB funds are used to: maintain the Centers' technical competence and ability to perform research: analysis and testing tasks: to solve present problems: and to reduce costs in developing programs, technologies, and materials. Beginning in FY 1998. a substantially de-scoped Advanced Projects activity was supported as a largely in-house effort to meet long-term Human Space Flight enterprise (HSF) requirements using modest amounts from this funding source. Efforts include system and mission analysis. integrated HSF Research and Technology (R&T) requirements definition and integration, modest R&T investments in a substantially de-scoped EVA technology demonstration project and limited investments in R&T required to support the integrated Office of Space Science/HEDS robotic efforts.

STRATEGY FOR ACHIEVING GOALS

The complex and technically challenging programs managed by the Office of Space Flight (OSF), now and in the future, are most effectively carried out by sustaining a NASA "core" institutional technical base. It is vital to preserve essential competency and excellence. Since FY 1994. the OSF centers have consolidated activities and have identified ways to economize the resources committed to ETB while maintaining ETB's benefits to the nation's human space flight program. Over the next few years, this consolidation will continue to generate savings through improved information resources management and contract streamlining. A prioritized core capability will include multi-program labs and test facilities, associated systems, equipment, and a full range of skills capable of meeting research, testing and simulation demands.

As the ETB budget is reduced, several activities will continue to refine current business practices. Mandatory equipment repair and replacement will be reassessed. Software applications for multi-program analytical tools will be implemented. The strategy to better manage the NASA investment in information processing resources includes aggressive actions to integrate and consolidate more ADP operations. ETB will ensure synergism among major NASA engineering programs. Awards for education and research tasks will be granted to support educational excellence and research learning opportunities in colleges and universities. A key challenge of the ETB strategy will be to provide a core capability for future human space flight endeavors with fewer resources. Future budget constraints dictate that new innovative processes be adopted to meet critical ETB core requirements, and that non-critical capabilities be streamlined or eliminated.

SCHEDULE AND OUTPUTS

Laboratories & facilities supported (KSC)	Maintains 11 science and engineering laboratories in support of 6 agency programs
Laboratories & facilities supported (JSC)	Maintains 156 science and engineering laboratories in support of 52 agency programs
Laboratories & facilities supported (MSFC)	Maintains science and engineering laboratories (7) and facilities (116) in support of 42 agency programs
Laboratories & facilities supported (SSC)	Maintains 3 science and engineering laboratories in support of 2 agency programs
NASA Minority University Research and Education Program at JSC, KSC, MSFC & SSC	Award education and research grants

ACCOMPLISHMENTS AND PLANS

The institutional technical base accomplished numerous activities in FY 1998. JSC used the majority of its ETB funding to maintain multi-program science and engineering laboratory capability. For example, ETB was used to complete the purchase and begin installation of a 5-axis milling machine, enabling JSC to meet fabrication requirements for the X-38 project as well as support other in-house engineering projects. ETB also supported the development of the Advanced Life Support Systems Integration Test Bed. This facility will serve as the Agency's focal point for development of closed-loop bio-regenerative life support system technologies, accommodate long-duration evaluations of regenerative biological and physicochemical life support systems with human test crews, and evaluate various aspects of human performance under isolated conditions. In addition, ETB was used to complete the lease-to-own-purchase of a mainframe processor through MSFC, ensuring adequate computing capability to support science and engineering analyses.

At KSC, ETB enables the Center's technical core capability to provide in-depth technical support for designs, development, and testing. The KSC laboratories perform activities for Shuttle, Space Station, Reusable Launch Vehicles, Payloads and Life Sciences programs. The KSC core laboratory environment provides customers with calibration and standards, non-destructive evaluation, component sampling and analysis, toxic vapor detection, sensor evaluation, radiological examination (computed topography), launch equipment and platform testing, and CAD/CAE. ETB also enables KSC to complete advanced planning studies including cost trade for future facility utilization; network security; and technology development tasks such as the cryogenic test bed. KSC also participates in programs to stimulate science and technical competence by participating in education and research grants with Historically Black Colleges and Universities (HBCU), Other Minority Universities (OMU), and Teacher/Faculty Enhancement programs.

The MSFC allocation of ETB funds supports 7 science and engineering laboratories and 166 facilities providing for a multitude of research activities. ETB funding enables the Center's technical core capability to provide in-depth technical support for design, development, testing, mission operations and evaluation of launch vehicles, space transportation systems, space stations, and payloads. ETB enables MSFC to conduct research and development efforts related to advanced propulsion systems and spacecraft, as well as engineering design, systems engineering, systems integration, material and process engineering, physical science research, test and evaluation, data analysis and system simulations. In FY 1999, MSFC will make the final lease payment on the Engineering Analysis Data System II (EADS II) Cray Triton. ETB funding will only be required to support operations and maintenance costs, which are reflected in the MSFC ETB budget. Beginning in FY 2000, all Supercomputing activities, currently provided by the EADS II, will be conducted at Ames Research Center. MSFC will also continue to evaluate the Center's ETB content for determination of how ETB funds will be distributed in a full cost budget environment. This includes developing and defining service pool rates for the Science and Engineering Service Pool and the Information Systems Service Pool. FY 2000 full cost simulation for ETB has been completed and lessons learned will be useful for POP 99 planning and preparation.

The SSC laboratories perform activities for NASA's Space Shuttle and Advanced Space Transportation Programs as well as for commercial propulsion test programs and resident governmental agencies. ETB funds maintain operability of the gas/materials analysis and calibration laboratories, provide for development of propulsion test technologies and maintain critical propulsion test engineering expertise in support of SSC's role as the agency's Lead Center for Propulsion Testing.

ETB funding includes the institutional Safety and Mission Assurance (S&MA) contractor workforce performing space flight activities at JSC, KSC and, MSFC. This workforce includes highly skilled personnel who are charged with responsibility to conduct Safety, Reliability & Quality Assurance assessments of conformance to reliability and quality standards. Surveillance of design, manufacturing and testing of hardware and software was conducted to ensure compliance with NASA safety and mission assurance requirements. The ETB resources will support independent assessments of flight and test equipment and testing operations, including product assurance tasks for the International Space Station program (ISS). However, product assurance tasks and funding for the ISS were transferred to the Office of Safety and Mission Assurance in FY 1998.

In FY 1998, JSC's SR&QA Directorate and the Shuttle Program began examining the base level of SR&QA competencies that benefited the Shuttle but were supported by ETB. Adequate support to the Shuttle SR&QA functions required some Shuttle SR&QA tasks to be funded by the Shuttle Program. All Shuttle SR&QA functions will be transferred to the Shuttle Program for management responsibility. The Shuttle Program and JSC's SR&QA Directorate will continue reviewing Shuttle SR&QA content with the goal of reducing, consolidating, or eliminating functions to lower costs while maintaining safety. In addition, responsibility for JSC's multi-program benefiting SR&QA functions is also transferring to the Shuttle and Station Programs. In addition, the FY 1999, budget constraints require JSC and WSTF to reduce support in the multi-program science and engineering laboratories and facilities. This will result in deferment of equipment replacements and upgrades and transfer of additional testing costs to programs and other customers.

ETB funding enables WSTF to maintain science and engineering core capabilities supporting testing and evaluations of spacecraft materials, components, and propulsion systems for safe human exploration and development of space. WSTF also employed these core capabilities to perform tasks for other Government agencies and the private sector on a reimbursable basis.

Marshall Space Flight Center also performed an analysis of SR&QA activities in an effort to properly align work content to the appropriate program, with the goal of reducing, consolidating, or eliminating functions to lower costs while maintaining safety. This activity resulted in a shift of work content from the Center Institutional function to the Space Shuttle Program. The Shuttle Program and the SR&QA Directorate will continue reviewing Shuttle SR&QA content with the goal of reducing, consolidating, or eliminating functions to lower costs while maintaining safety.

The Engineering and Technical Base also supports Information Resource Management (IRM). IRM processing achieved efficiencies and improved economies of scale through the consolidation of IBM-compatible mainframes supporting administrative and programmatic automated data processing (ADP) services at the NASA ADP Consolidation Center (NACC) located at MSFC. Consolidation of user requirements and information technology plans were fully implemented in FY98; however, the NACC continues to seek new and innovative ways to achieve cost savings.

The NACC provides supercomputing capability for its customers for engineering and scientific computer-intensive applications seven days a week. The NACC supercomputing facility was established in FY 1994 and is managed through the MSFC NACC Project Office. The NACC supercomputing facility includes a mainframe located at MSFC and a smaller distributed system located at JSC, supporting customers at both Centers. The NACC supercomputer facilities include hardware and software to conduct thermal radiation analyses, computational fluid dynamics, structural dynamics and stress analyses for NASA programs such as the Space Shuttle, X-33, X-34, Space Station, and Reusable Launch Vehicle. The facilities also conduct certification and engineering performance evaluation of flight and test data.

In FY 1999, JSC will begin receiving workstation support through the Outsourcing Desktop Initiative for NASA (ODIN). JSC's Information Systems Directorate will work with the selected vendor to ensure adequate scientific, technical, and engineering computing capability is received at the lowest possible cost. In FY 2000, ETB will continue to provide vital support to JSC science and engineering lab infrastructure. FY 2000 contains many critical programmatic milestones that will require extensive support from our labs. NASA needs to perform many critical studies, tests, and analyses for many activities. These include: monitoring human life support and crew health as we begin to inhabit Station in FY 2000; and ensuring the Shuttle can safely operate and transport Station hardware and astronaut personnel; ensuring smooth and safe operations of personnel and equipment during the Station assembly EVAs. In addition, ETB will keep our labs operational to perform exploration and development studies.

In cooperation with the goals of the NASA Minority University Research and Education Program, ETB enables the Space Flight Centers to participate in programs to stimulate science and technical competence in the nation. The ETB program enabled the Centers to award education and research grants to Historically Black Colleges and Universities (HBCU). A total of 40 grants were awarded in FY 1998. Examples include: solution crystal growth in low gravity; organic fiber optic sensors; hydrology, soil climatology, and remote sensing; and cytogenic investigations into radiosensitivity, genetic instability and neoplasti. JSC will be awarding approximately $1.0 million in new research grants to Historically Black Colleges and Universities and Other Minority Universities. Both KSC and SSC also participate in programs to stimulate science and technical competence by participating in education and research grants with Historically Black Colleges and Universities (HBCU), Other Minority Universities (OMUs).

In FY 1999 and FY 2000 the ETB budget will continue to be reduced as the reductions resulting from the Agency's Zero-Base Review (ZBR) are implemented. These reductions include a reduced level of science and engineering lab support to human space flight programs, streamlined technical operations, additional ADP consolidation activities, and reduced education and research awards funding. These reductions will require that all Centers continue to assess their range of workforce skills, analytical tools and facilities dedicated to ensure their ability to provide space flight institutional engineering support for future human space flight programs and the existing customer base. Center assessments will focus on maintaining core support for design, development, test and evaluations, independent assessments, simulation, operations support, anomaly resolution, and systems engineering activities.

In FY 1999, KSC will continue to achieve ZBR-recommended reductions in FY 1999 by reengineering CAD/CAE services including migration to PC platform and elimination of VAX mainframe/software and associated maintenance. MSFC and SSC will continue institutional support while continuing to strive for institutional efficiencies. In FY 1999 and FY 2000, KSC will continue to achieve cost efficiencies in the operation of existing core laboratories and associated technical ADP services which will enable necessary equipment/system upgrades and implementation of strategic core technical development initiatives that support our Center of Excellence assignment.

In FY 1999, ETB will continue to conduct business in the current mode, but will be preparing for implementation of the Agency's Full Cost budget structure. In FY 2001, all Space Flight Centers will transition to a Full Cost budget structure environment. At this time the ETB budget will be phased out. Under Full Cost budget structure, ETB activities will be planned, justified and budgeted for by the benefiting customer receiving the service. All Space Flight Centers previously providing these ETB services will define and establish service pools and usage costs in order to recover operating costs. Service pools will be established for testing services, science and engineering laboratory capability, and computer operations. Space Flight Centers will continue to provide the highest quality science and engineering analyses for NASA's programs and external customers during and following this transition, to the Full Cost budget structure.

In FY 2000, there will be an effort to include systems analysis and modest investments in research and technology to meet long-term HSF requirements included in the ETB budget. Systems Analysis will provide for overall planning and analysis for development of new technology, focusing on innovative, high-leverage technologies and approaches which will enable the development of new capabilities to meet future human space flight needs, and providing the opportunity for enhanced synergy between ongoing programs and future HEDS objectives. It includes the following activities:

- Overall technical integration and development of technical requirements, technology roadmaps, and investment strategies;
- Evaluation of alternative mission approaches and technologies;
- Development of advanced transportation system architectures and technology requirements;
- Definition of R&T for Advanced Power, Information Systems Technology, and Advanced Sensors;
- System & concept definition and identification of proof-of-concept tests/ demonstrations for key emerging HEDS technologies/systems;
- ISS evolution systems analysis to determine far-term mission requirements and concepts for cost reduction and performance enhancement; and
- Identification of candidate HEDS payloads for future Mars robotics missions providing low cost environmental data and technology demonstrations that are necessary to enable safe exploration missions in the future.

Intelligent Synthesis Environment (ISE) testbeds will be initiated in FY 1999 to provide NASA engineers and scientists with the tools and infrastructure to facilitate the development of new technology, analysis and modeling tools for mission architectures. The centers' ISE requirements are further addressed in the agency's FY 2000 ISE initiative for which funding is requested in the Research and Technology Base of the Aeronautics program with an increased focus on commercial space development initiatives.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

The Science, Aeronautics and Technology appropriation provides funding for the research and development activities of NASA. This includes funds to extend our knowledge of the Earth, its space environment, and the universe; and to invest in new aeronautics and advanced space transportation technologies that support the development and application of technologies critical to the economic, scientific and technical competitiveness of the United States.

STRATEGY FOR ACHIEVING GOALS

Funding included in the Science, Aeronautics and Technology appropriation supports the program elements of NASA's four Enterprises:

Human Exploration of Space - uses the microgravity environment of space to conduct basic and applied research to understand the effect of gravity on living systems and to conduct research in the areas of fluid physics, materials science and biotechnology.

Space Science - seeks to answer fundamental questions concerning the galaxy and the universe; the connection between the Sun, Earth and heliosphere; the origin and evolution of planetary systems; and, the origin and distribution of life in the universe.

Earth Science - to understand the total Earth system and the effects of natural and human-induced changes on the global environment.

Aero-Space Technology - to pioneer high-payoff, critical technologies with effective transfer of design tools and technology products to industry and government.

Funding is also included to provide highly reliable, cost effective telecommunications services in support of NASA's science and aeronautics programs, and to conduct NASA's Agencywide university, minority university, and elementary and secondary school programs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1998	FY 1999	FY 2000
SCIENCE, AERONAUTICS AND TECHNOLOGY	**5,690.0**	**5,653.9**	**5,424.7**
SPACE SCIENCE	2,043.8	2,119.2	2,196.6
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	214.2	263.5	256.2
EARTH SCIENCE	1,417.3	1,413.8	1,459.1
AERO-SPACE TECHNOLOGY	1,483.9	1,338.9	1,006.5
MISSION COMMUNICATION SERVICES	400.8	380.0	406.3
ACADEMIC PROGRAMS	130.0	138.5	100.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

SCIENCE, AERONAUTICS AND TECHNOLOGY

For necessary expenses, not otherwise provided for, in the conduct and support of science, aeronautics and technology research and development activities, including research, development, operations, and services; maintenance; construction of facilities including repair, rehabilitation, and modification of real and personal property, and acquisition or condemnation of real property, as authorized by law; space flight, spacecraft control and communications activities including operations, production, and services; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [$5,653,900,000] *$5,424,700,000*, to remain available until September 30, [2000] 2001. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Acts, 1999.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCIENCE, AERONAUTICS AND TECHNOLOGY

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

		BUDGET PLAN	
	FY 1998	FY 1999	FY 2000
SCIENCE, AERONAUTICS AND TECHNOLOGY	**508.0**	**599.1**	**576.6**
SPACE SCIENCE	53.6	90.2	77.1
LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS	0.6	1.4	1.5
EARTH SCIENCE	308.9	345.9	366.8
AERO-SPACE TECHNOLOGY	65.5	83.9	60.6
MISSION COMMUNICATION SERVICES	14.9	11.6	9.1
ACADEMIC PROGRAMS	0.1	0.8	.1
LAUNCH SERVICES	64.4	65.3	61.4

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

DISTRIBUTION OF SCIENCE, AERONAUTICS, AND TECHNOLOGY BY INSTALLATION (Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Space Science	1998	2,043,800	11,069	127,988	238,014	0	81,944	0	16,474	32,121	793,997	668,180	74,013
	1999	2,119,200	14,395	206,166	174,057	0	108,822	0	11,991	22,141	790,781	720,947	69,900
	2000	2,196,600	10,538	184,142	142,012	0	99,381	0	10,884	20,720	786,253	892,917	49,753
Life and Microgravity Sciences and Applications	1998	214,200	54,300	5,200	50,800	0	25,000	0	400	34,800	10,500	13,200	20,000
	1999	263,500	75,800	5,000	65,800	0	34,600	0	200	37,400	9,100	13,800	21,800
	2000	256,200	73,200	3,800	65,500	0	32,700	0	0	38,000	6,100	14,300	22,600
Earth Science	1998	1,417,300	400	100,620	25,882	37,793	8,560	21,456	39,876	7,414	930,000	219,337	25,962
	1999	1,413,800	0	92,700	18,600	40,400	10,200	16,900	34,900	0	928,300	222,100	49,700
	2000	1,459,100	0	66,900	38,300	32,700	13,300	19,000	59,900	0	916,000	251,700	61,300
Aeronautical Research and Technology	1998	920,100	669	0	2,302	0	229,699	93,425	325,008	249,992	5,566	1,387	12,052
	1999	768,900	1,085	0	2,428	0	198,040	77,809	265,633	206,832	7,244	1,769	8,060
	2000	620,000	0	0	2,133	0	196,711	91,405	163,329	158,235	0	0	8,187
Advanced Space Transportation Technology	1998	417,100	4,757	668	325,935	16,990	12,258	6,230	13,958	11,500	1,080	9,046	14,678
	1999	429,600	1,745	1,036	321,248	30,340	10,156	7,413	22,650	11,636	40	4,166	19,170
	2000	254,000	934	900	207,106	1,269	7,605	3,093	13,546	8,567	30	1,646	9,304
Commercial Technology	1998	146,700	13,325	6,470	30,620	4,107	16,733	2,916	18,451	20,107	27,425	4,200	2,346
	1999	140,400	16,452	7,822	21,398	4,306	13,364	3,312	17,648	19,799	26,391	2,220	7,688
	2000	132,500	16,800	5,100	21,800	4,000	12,900	3,400	17,600	15,500	24,100	9,200	2,100
Total Aeronautics & Space Transportation Technology	1998	1,483,900	18,751	7,138	358,857	21,097	258,690	102,571	357,417	281,599	34,071	14,633	29,076
	1999	1,338,900	19,282	8,858	345,074	34,646	221,560	88,534	305,931	238,267	33,675	8,155	34,918
	2000	1,006,500	17,734	6,000	231,039	5,269	217,216	97,898	194,475	182,302	24,130	10,846	19,591
Mission Communication Services	1998	400,800	6,700	0	2,100	0	0	14,600	0	9,800	205,600	159,400	2,600
	1999	380,000	5,500	0	300	0	0	12,600	0	10,100	187,400	161,000	3,100
	2000	406,300	8,800	0	300	0	0	14,900	0	10,100	192,000	174,900	5,300
Academic Programs	1998	130,000	3,600	4,700	10,900	2,000	7,400	1,700	3,900	8,600	73,900	2,900	10,400
	1999	138,500	4,200	6,500	8,500	4,100	6,400	3,600	6,600	14,400	70,400	4,400	9,400
	2000	100,000	3,500	5,100	7,700	3,500	5,800	2,800	5,500	3,200	49,500	4,000	9,400
TOTAL SCIENCE, AERONAUTICS AND TECHNOLOGY	1998	5,690,000	94,820	245,646	686,553	60,890	381,594	140,327	418,067	374,334	2,048,068	1,077,650	162,051
	1999	5,653,900	119,177	319,224	612,331	79,146	381,582	121,634	359,622	322,308	2,019,656	1,130,402	188,818
	2000	5,424,700	113,772	265,942	484,851	41,469	368,397	134,598	270,759	254,322	1,973,983	1,348,663	167,944

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE | **SPACE SCIENCE**

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
		(Thousands of Dollars)		
* Advanced x-ray astrophysics facility	112,200	41,000	--	SAT 1-09
* Space infrared telescope facility	70,200	119,700	125,000	SAT 1-12
* Hubble space telescope (development)	144,900	161,400	140,400	SAT 1-15
* Relativity (GP-B) mission	70,800	57,400	40,500	SAT 1-17
* Thermosphere, ionosphere, mesosphere energetics and dynamics	64,400	49,300	16,000	SAT 1-20
* Stratospheric observatory for infrared astronomy	45,800	58,200	45,100	SAT 1-22
Payload and instrument development	18,000	28,900	10,000	SAT 1-25
* Explorers	169,300	196,000	151,000	SAT 1-29
* Discovery	100,000	124,900	180,500	SAT 1-37
* Mars surveyor	187,900	228,400	250,700	SAT 1-41
Mission operations	138,700	106,300	85,300	SAT 1-46
Supporting research and technology	894,000	945,200	1,152,100	SAT 1-54
Launch services	27,600	--	--	SAT 1-80
Construction of facilities (building 21 @ GSFC)	--	2,500	--	
Expendable launch vehicles (non-add and included above)	[212,900]	[206,500]	[186,900]	
Total	2,043,800	2,119,200	2,196,600	

*Total Cost information is provided in the Special Issues section

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2000 ESTIMATES

BUDGET SUMMARY

Distribution of Program Amount by Installation	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Johnson Space Center	11,069	14,395	10,538
Kennedy Space Center	127,988	206,166	184,142
Marshall Space Flight Center	238,014	174,057	142,012
Ames Research Center	81,944	108,822	99,381
Langley Research Center	16,474	11,991	10,884
Glenn Research Center	32,121	22,141	20,720
Goddard Space Flight Center	793,997	790,781	786,253
Jet Propulsion Laboratory	668,180	720,947	892,917
Headquarters	74,013	69,900	49,753
Total	2,043,800	2,119,200	2,196,600

PROGRAM GOALS

Humans have a profound and distinguishing imperative to understand our origin, our existence, and our fate. For millennia, we have gazed at the sky, observed the motions of the Sun, Moon, planets, and stars, and wondered about the universe and the way we are connected to it. The Space Science Enterprise serves this human quest for knowledge. As it does so, it seeks to inspire our Nation and the world, to open young minds to broader perspectives on the future, and to bring home to every person on Earth the experience of exploring space.

The mission of the Space Science Enterprise is to solve mysteries of the universe, explore the solar system, discover planets around other stars, search for life beyond Earth; from origins to destiny, chart the evolution of the universe and understand its galaxies, stars, planets, and life.

In pursuing this mission, we develop, use, and transfer innovative space technologies that provide scientific and other returns to all of NASA's Enterprises, as well as globally competitive economic returns to the Nation. We also use our knowledge and discoveries to enhance science, mathematics, and technology education and the scientific and technological literacy of all Americans.

In accomplishing its mission, the Space Science Enterprise addresses most directly the following NASA fundamental questions:

How did the universe, galaxies, stars, and planets form and evolve? How can our exploration of the universe and our solar system revolutionize our understanding of physics, chemistry, and biology?

Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth? Are there Earth-like planets beyond our solar system?

The four long-term goals of the Space Science Enterprise are:

Establish a virtual presence throughout the solar system, and probe deeper into the mysteries of the universe and life on Earth and beyond—a goal focused on the fundamental science we will pursue;

Pursue space science programs that enable, and are enabled by, future human exploration beyond low-Earth orbit—a goal exploiting the synergy with the human exploration of space;

Develop and utilize revolutionary technologies for missions impossible in prior decades—a goal recognizing the enabling character of technology; and

Contribute measurably to achieving the science, mathematics, and technology education goals of our nation, and share widely the excitement and inspiration of our missions and discoveries—a goal reflecting our commitment to education and public outreach.

STRATEGY FOR ACHIEVING GOALS

Science

The Space Science Enterprise pursues the study of origins, as well as studies of the evolution and destiny of the cosmos, by establishing a continuum of exploration and science. It creates a virtual presence in the solar system, exploring new territories and investigating the solar system in all its complexity. It simultaneously probes the universe to the beginning of time, looking ever deeper with increasingly capable telescopes, scanning the entire electromagnetic spectrum from gamma rays to radio wavelengths. It also sends probes into interstellar space, beginning a virtual presence even beyond the solar system.

The strategy of the Enterprise is to conduct world-class research, to maximize the scientific yield from our current missions, and to develop and deploy new missions within the "faster, better, cheaper" framework of a revolutionized NASA.

Fulfilling one major commitment of previous strategic planning, the Enterprise will complete the deployment of the four "Great Observatories" with the launch of the Advanced X-ray Astrophysics Facility (AXAF) in 1999 and the Space Infrared Telescope Facility

(SIRTF) in 2001. Complementing the discoveries of the Hubble Space Telescope and the Compton Gamma Ray Observatory launched earlier in this decade, AXAF and SIRTF are certain to add to this bounty and help unravel the mysteries of the universe.

With the July 4, 1997, landing of the Mars Pathfinder, and the 1998 discovery of water ice on the Moon by Lunar Prospector (both missions of the Discovery series of spacecraft), the Enterprise visibly demonstrated that such "faster, better, cheaper" programs can yield exciting and inspiring achievements as well as a wealth of knowledge. Through programs such as Discovery and Explorer, the Enterprise will continue to accept prudent risk, shorten development time, explore new conceptual approaches, streamline management, and make other changes to enhance efficiency and effectiveness.

A key aspect of our strategic planning is to ensure the Enterprise acquires the advice of the external science community, and in particular the National Academy of Sciences. The Enterprise is also ensuring science community input by utilizing peer review in the Discovery, Explorers and Supporting Research and Technology programs. In addition, there is extensive collaboration with this community, international partners, and other federal agencies, such as the National Science Foundation, Department of Defense, and Department of Energy, in the conduct of our missions, research and technology.

As a visible link to future human exploration beyond Earth orbit, Space Science Enterprise robotic missions help develop the scientific knowledge such ventures will need. In the long term, the Enterprise will benefit from the opportunities human exploration will offer to conduct scientific research that may stretch beyond the capabilities of robotic systems.

Education and public outreach

Our education and public outreach goals and objectives involve establishing new directions for the Space Science Enterprise. The traditional role of the Enterprise in supporting graduate and postgraduate professional education—a central element of meeting our responsibility to help create the scientific workforce of the future—is being expanded to include a special emphasis on pre-college education and on increasing the public's knowledge, understanding, and appreciation of science and technology.

Our strategy for realizing our education and public outreach goals begins with incorporating education and public outreach as an integral component of all of our activities—flight missions and research programs. It focuses on identifying and meeting the needs of educators and on emphasizing the unique contributions the Space Science Enterprise can make to education and to enhancing the public understanding of science and technology. It is directed towards optimizing the use of limited resources; encouraging a wide variety of education and outreach activities; channeling individual efforts towards high-leverage opportunities; developing high-quality education and outreach activities and materials having local, state, regional, and national impact; and ensuring that the results of our education programs are catalogued, evaluated, archived and widely disseminated. Our strategy supports NASA's overall education program and is aligned with NASA's efforts to ensure that participation in NASA missions and research programs is as broad as possible. It is centered on brokering and facilitating the formation of partnerships between space scientists and a wide range of individuals and institutions across the country engaged in education and in communicating science and technology to the public. It makes contributing to education and outreach the collective responsibility of all levels of management in the Space Science Enterprise and all the participants in the Space Science program.

To achieve our education and public outreach goals and objectives, the Space Science Enterprise will adopt the following operating principles. The Space Science Enterprise will:

- Involve scientists in education and outreach in ways that enhance core Space Science research goals
- Make a long-term sustained commitment to integrating education and outreach into Space Science missions and research programs by: 1) providing resources; 2) building education and outreach into all aspects of the Space Science program; and 3) recognizing and rewarding contributions to education and outreach
- Support local, state, and national efforts directed towards systemic reform of science, mathematics, and technology education in close coordination with NASA's Education Division
- Base Space Science-developed educational products and activities on the criteria contained in the national Mathematics, Science, and Technology Education Standards
- Provide meaningful opportunities for student and teacher participation in Space Science research programs and missions and, in particular, emphasize the development of new opportunities for participation by underserved and underutilized groups
- Enhance the breadth and effectiveness of partnerships among scientists, educators, contractors, and professional organizations as the basis for Space Science education and outreach activities by: 1) focusing on high-leverage opportunities; 2) building on existing programs, institutions, and infrastructure; 3) emphasizing collaborations with planetariums and science museums; 4) coordinating with other ongoing education and outreach efforts inside NASA and within other government agencies; and 5) involving the contractors in the Space Science Enterprise's education/outreach programs
- Make materials widely available and easily accessible, using modern information and communication technologies where appropriate
- Evaluate its education and outreach programs for quality, impact, and effectiveness

The comprehensive approach to education and public outreach developed by the Space Science Enterprise to put these principles into practice is described in more detail in the October 15, 1996 report "Implementing the Office of Space Science Education/Public Outreach Strategy", available in full on the World Wide Web at http://www.hq.nasa.gov/office/oss/edu/imp_plan.htm

The approach outlined in this report has been explicitly designed to take advantage of, be coupled to, be compatible with, and build upon the very large investments in education being made by school districts, individual states, and other federal agencies—particularly by the National Science Foundation and the Department of Education. By pursuing such a systematic approach, the impact of a modest investment in education and outreach can be enormously amplified, thereby enabling the Space Science

Enterprise to make a significant, long-term, and long-lasting contribution to education and the public understanding of science in the United States.

During FY 2000, we will successfully achieve at least 7 of the following 8 objectives. 1) Each new Space Science mission will have a funded education and outreach program. 2) By the end of FY00 10% of all Space Science research grants will have an associated education and outreach program underway. 3) 26 states will have Enterprise-funded education or outreach programs planned or underway. 4) At least 5 research, mission development/operations or education programs will have been planned/undertaken in HBCUs, HSIs, or Tribal Colleges, with at least one project underway in each group. 5) At least 3 national and two regional educational or outreach conferences will be supported with a significant Space Science presence. 6) At least 3 exhibits or planetarium shows will be on display. 7) An on-line directory providing enhanced access to major Space Science-related products and programs will be operational by end of the fiscal year. 8) A comprehensive approach to assessing the effectiveness and impact of the Space Science education and outreach efforts will be under development, with a pilot test of the evaluation initiated.

Technology development and transfer

A number of enabling technologies have been identified for the Space Science program, and prioritizing them is one of the most important technology planning tasks. These fall into two general categories:

- Technologies that provide fundamental capabilities without which certain objectives cannot be met, or that open completely new mission opportunities. Fundamental enabling capabilities include developments such as high-precision deployable structures that maintain optical paths to within fractions of a wavelength of light. These are required for studying extra-solar planets through optical interferometry, as well as for the next generation of large space telescopes that will see to the edge of the Universe.

- Technologies that reduce cost and/or risk to such a degree that they enable missions that would otherwise be economically unrealistic. Highly capable micro-electronics and micro-spacecraft systems, by virtue of their broad applicability and potential for reducing mission costs and development times, enable missions which would otherwise be prohibitively expensive. The importance of these systems and their commercial potential make them one of our most important technology investment areas.

Both types of developments are essential to the overall goals of the Space Science program. A well-structured technology investment portfolio must recognize and balance the importance of both categories. A key aspect of this investment portfolio is that it utilizes partnerships with industry, other government agencies, and universities in the planning, development and implementation of Space Science missions. Many capabilities have been transferred and infused into industry from DoD or NASA core technology support, and the space science research community uses the resulting industrial space infrastructure for mission planning and development. Industry partnerships allow for a more efficient linkage between the builders and users of flight hardware. The identification, development and utilization of advanced technology dramatically lowers instrument, spacecraft, and mission operations costs and contributes to the long-term capability and competitiveness of American industry.

We have identified a number of key capabilities for which we are developing near-term (several years), measurable performance objectives. Achieving these objectives will require significant near-term investment. The objectives are part of an integrated technology roadmap which contains milestones against which our progress will be assessed.

To develop these capabilities, the Space Science Enterprise technology program is organized into three elements:

1. A *Core Program* of research supporting mission-specific technologies for Space Science and cross-cutting spacecraft and robotics technologies for multiple NASA Enterprises. The Core Program supports enabling technologies for the next generation of high performance and cost-effective Space Science missions. Retiring technological risk early in the mission design cycle, while emphasizing innovation to reach previously unattainable goals in mass reduction and performance, are key to the success of many of the missions planned for the next century.

   Cross-Enterprise technology development is generally multi-mission in nature and tends to focus on the earlier stages of the technology life-cycle. Emphasis is on basic research into physical principles, formulation of applications concepts, and component-level performance evaluation. While these developments may extend all the way to subsystem-level development and test for nearer-term missions, the focus of this program is on technological developments to enable revolutionary rather than incremental increases in capability and/or efficiency. These cross-cutting developments are the foundation for most new spacecraft, robotics, and information technologies eventually flown on NASA missions. Starting in FY 2000, new funding in Cross-Enterprise technologies is provided for technology initiatives to increase NASA's space science return many fold through revolutionary capabilities in the areas of networking, intelligent systems, nanotechnology, communications, lightweight structures, miniaturization, mobility, and propulsion for future robotic spacecraft and rovers.

2. Several *Focused Programs* are dedicated to specific high-priority technology areas. An aggressive technology development approach is used that allows all major technological hurdles to be cleared prior to a science mission's development phase. This approach can encompass developments from basic research all the way to infusion into science missions. The requirements are driven by the needs of Space Science, but other Enterprises are likely to benefit from them. Focused programs also includes mission studies, which is the first phase of the flight program development process. Scientists work collaboratively with technologists and mission designers to develop the most effective alignment of technology development programs with future missions. This collaboration enables intelligent technology investment decisions by fully exploring the design and cost trade space. These studies will utilize new techniques for integrated design and rapid prototyping to ensure that realistic and implementable decisions are reached.

   There are four Focused Programs:

   Advanced Deep Space System Development. This program will develop, integrate, and test revolutionary technologies for solar system exploration. Emphasis will be on micro-avionics, autonomy, computing technologies, and advanced power systems. Along with other technologies, these will be integrated as advanced engineering-model flight systems to form the basis for the new generation of survivable, highly capable micro-spacecraft.

Astronomical Search for Origins Technology. This program will develop critical technologies for studies of the early Universe and of extra-solar planetary systems. Included are large lightweight deployable structures, precision metrology, optical delay lines, and other technologies for space-based interferometry. Also included are technologies such as inflatable structures and large lightweight optics required by many proposed missions and concepts.

Structure and Evolution of the Universe Technology. This program will provide the technologies required for missions focused on understanding how the structure of our Universe emerged from the Big Bang, how the Universe is continuing to evolve, and what will be the fate of the Universe. Examples of technology in this area include sensors, detectors, and other instruments, as well as cryocoolers and lightweight optical systems.

Sun-Earth Connections Technology. This program will develop the technologies needed for missions focused on understanding long-term and short-term solar variability, and how solar processes affect the Earth. Technologies supported in this area include thermal shielding, integrated fields and particles sensors, high-temperature solar arrays, nanosatellites, and satellite constellations.

3. A *Flight Validation Program* called the "New Millennium Program" completes the technology development process by providing flight validation of breakthrough technologies to enable new science missions. New Millennium is driven by the need to reduce the cost of future science missions, mitigate the risk to the first users of new technologies, and to rapidly infuse new technologies into future missions. In keeping with the focus of the New Millennium Program (NMP) on providing flight validation of broadly applicable technologies, the NMP Deep Space-3 flight demonstrator project has been moved to the Astronomical Search for Origins focused program. This demonstrator will validate interferometry technologies to benefit future Origins missions such as Terrestrial Planet Finder. Similarly, the Deep Space-4 mission (Champollion) has been moved to the Deep Space Systems focused program, since this mission to land on the surface of a comet benefits the objectives of the Solar System Exploration scientific theme. The New Millennium Program is jointly funded by the Space Science Enterprise and the Earth Science Enterprise.

SCHEDULE & OUTPUTS

The Office of Space Science (OSS) has continued to work with the Office of Management and Budget and the NASA Advisory Committee to develop metrics in response to the Government Performance and Results Act (GPRA) of 1993. We have developed metrics for each individual Space Science program that will be incorporated into the Enterprise's FY 2000 Performance Plan. These metrics are reflected in the "Measures of Performance" section for each program below.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED X-RAY ASTROPHYSICS FACILITY

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Advanced X-Ray Astrophysics Facility development *	112,200	41,000	--
ELV (Non-add	[8,300]	[2,000]	[--]

* Total cost information is provided in the Special Issues section

PROGRAM GOALS

The Advanced X-ray Astrophysics Facility (AXAF) is the third of NASA's Great Observatories, which include the Hubble Space Telescope and the Compton Gamma Ray Observatory. AXAF will observe matter at the extremes of temperature, density and energy content. Previous X-ray missions, such as the Small Astronomical Satellite-C and the Einstein Observatory have demonstrated that observations in the X-ray band provide a powerful probe into the physical conditions of a wide range of astrophysical systems. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, AXAF will provide unique and crucial information on the nature of objects ranging from nearby stars like our Sun to quasars at the edge of the observable universe. Some of the major scientific questions addressed by AXAF include:

What is the age and size of the universe? AXAF will provide an independent measurement at X-ray wavelengths of the Hubble Constant, which determines the answers to these questions. AXAF will be able to resolve and detect individual bright binary sources in galaxies within the Virgo cluster, as well as sources in intermediate galaxies. Thus, the population of bright X-ray sources in hundreds of galaxies can be determined. Since high-energy X-rays are unaffected by obscuring material, the brightness of sources can be accurately measured and the hypothesis that these sources, or a subset of them, are "standard candles" can be accurately tested. If such "standard candles" are found, distances to nearby galaxies can be accurately determined. These distances are a crucial step in the derivation of the Hubble Constant and the potential of these measurements is truly exciting.

What is dark matter? Dark matter accounts for more than 90% of the mass of the universe, but its composition remains a total mystery. The gravitational effects of dark matter have proven its existence, but it has yet to be identified. It may be massive amounts of ordinary matter in the form of small, non-radiating objects yet to be detected, or it may be some exotic new form of matter. AXAF will be able to map the distribution of dark matter in distant clusters of galaxies, contributing to our understanding of this enigma.

What is the X-ray background radiation? Other X-ray missions have seen a faint X-ray background emission covering the entire sky, the nature of which is uncertain. AXAF is expected to detect quasars and active galaxies 100 times fainter than the Einstein Observatory could, and can thus look to significantly greater distances. This is unknown territory, except that the integrated emission from many unresolved faint sources probably contributes most of the X-ray background. Deep AXAF observations will come close to imaging this background and will provide a sample of distant objects which record the state of the universe at early times.

STRATEGY FOR ACHIEVING GOALS

The Marshall Space Flight Center (MSFC) was assigned responsibility for managing the AXAF Project in 1978 as a successor to the High Energy Astrophysics Observatory (HEAO) program. The scientific payload was selected through an Announcement of Opportunity (AO) in 1985 and confirmed for flight readiness in 1989. TRW was selected as prime spacecraft contractor for the mission, with major subcontracts to Hughes Danbury (mirror development), Eastman Kodak (High Resolution Mirror Assembly -- HRMA), and Ball Aerospace (Science Instrument Module - SIM). The Smithsonian Astrophysical Observatory (SAO) also has significant involvement throughout the program. AXAF will be launched on the Shuttle with an Inertial Upper Stage (IUS) provided by Boeing. International contributions are being made by the Netherlands (an instrument), Germany (an instrument), Italy (detector test facilities), and the United Kingdom (microchannel plates and science support).

AXAF was given new start approval in FY 1989, with full-scale development contingent upon demonstrating the challenging advances in mirror metrology and polishing technology. The first pair of mirrors was fabricated and tested in a specially designed X-ray Calibration Facility (XRCF) at MSFC in 1991, and the X-ray results validated the metrology and polishing. With the success of this Verification Engineering Test Article (VETA) #1 demonstration, the program proceeded fully into design and development.

The AXAF program was restructured in 1992 in response to decreasing future funding projections for NASA programs. The original baseline was an observatory with six mirror pairs, a 15-year mission in low-Earth orbit, and shuttle servicing. The restructuring produced AXAF-I, an observatory with four mirror pairs to be launched into a high-Earth orbit for a five-year lifetime, and AXAF-S, a smaller observatory flying an X-Ray Spectrometer (XRS). A panel from the National Academy of Sciences (NAS) endorsed the restructured AXAF program. The FY 1994 AXAF budget was reduced by Congress, resulting in termination of the AXAF-S mission. The Committees further directed that residual FY 1994 AXAF-S funds be applied towards development of a similar instrument payload on the Japanese Astro-E mission to mitigate the science impact of losing AXAF-S. Funding for Astro-E is requested within the Payload and Instrument Development line.

SCHEDULE & OUTPUTS

Deliver Observatory to KSC Plan: June 1998 Revised: January 1999	Observatory integration and systems testing completed at TRW. Ship to launch site and begin integration with upper stage, final performance testing, and integration in Shuttle. Delayed by need for additional testing and review to ensure mission success.

Launch Observatory Plan: August 1998 Revised: April 1999/Under Review	Shuttle deployment into low-Earth orbit followed by upper stage delivery to highly elliptical operational orbit. Delayed until April 1999 by need for additional testing and review to ensure mission success. Additional delay, yet to be determined, will result from recently discovered problems with circuit boards.

ACCOMPLISHMENTS AND PLANS

As a result of delays at TRW, first identified over a year ago, the delivery of AXAF has slipped to January 1999, and the launch is now scheduled for April 1999. This delay was caused by the need to perform additional software development and testing, as well as the need for TRW to provide sufficient assurance to NASA that the spacecraft systems and both ground and flight software and procedures have been tested sufficiently to enable a successful mission. Unlike the Hubble Space Telescope, AXAF will not be serviceable on orbit by the Space Shuttle after deployment. Accordingly, NASA believes that it was prudent to conduct additional reviews prior to launch.

The delays have, to date, added about eight months to the schedule that was established over six years ago, and have added approximately $49 million (about 3%) to the cost of building and launching the Observatory. Moreover, in mid-January 1999, following the successful completion of AXAF testing, TRW discovered a problem with circuit boards on some of their spacecraft, including AXAF. The project is currently investigating the extent of the problem on AXAF; however, it appears that the minimum launch delay will be five weeks, or until May 1999. The potential exists for a much longer delay, but at this time the scope of the problems, and the length of the delay, are yet to be determined. NASA will not launch AXAF until we are certain that we have a world-class observatory that has been thoroughly tested and meets all requirements. NASA will inform the Administration and Congress of the new AXAF launch date as soon as possible.

Following launch, the spacecraft will enter a period of checkout, followed by the start of science operations.

In December 1998 NASA announced that AXAF has been renamed the Chandra X-ray Observatory, in honor of the late Indian-American Nobel laureate, Subrahmanyan Chandrasekhar. Chandrasekhar made fundamental contributions to the theory of black holes and other phenomena that the Chandra X-ray Observatory will study. His life and work exemplify the excellence that we hope to achieve with this great observatory

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE INFRARED TELESCOPE FACILITY

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
SIRTF development *..	70,200	119,700	125,000
ELV (Non-add	--	[8,000]	[23,900]

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Space Infrared Telescope Facility (SIRTF) mission is to explore the nature of the cosmos through the unique windows available in the infrared portion of the electromagnetic spectrum. These windows allow infrared observations to explore the cold Universe by looking at heat radiation from objects which are too cool to radiate at optical and ultraviolet wavelengths; to explore the hidden Universe by penetrating into dusty regions which are too opaque for exploration in the other spectral bands; and to explore the distant Universe by virtue of the cosmic expansion, which shifts the ultraviolet and visible radiation from distant sources into the infrared spectral region. To exploit these windows requires the full capability of a cryogenically-cooled telescope, limited in sensitivity only by the faint infrared glow of the interplanetary dust. SIRTF is the fourth of NASA's Great Observatories, which include the Hubble Space Telescope, the Compton Gamma Ray Telescope, and the Advanced X-Ray Astrophysics Facility. By completing NASA's family of Great Observatories, an infrared capability will enable the full power of modern instrumentation to be brought to bear, across the entire electromagnetic spectrum, on the central questions of modern astrophysics. Many of these questions can be unraveled only by the full physical picture that this broad spectral coverage uniquely provides.

Rather than simply "descoping" the original Titan-class SIRTF -- the original "Great Observatory" concept -- to fit within a $400 million (FY94) cost ceiling imposed by NASA, scientists and engineers have instead redesigned SIRTF from the bottom-up. The goal was to substantially reduce costs associated with every element of SIRTF -- the telescope, instruments, spacecraft, ground system, mission operations, and project management. With an eye towards cost, and in recognition of the unprecedented sensitivity afforded by the latest arrays, the SIRTF Science Working Group identified a handful of the most compelling problems in modern astrophysics for which SIRTF could make unique and important contributions. These primary science themes, which have received the endorsement of the National Research Council's Committee on Astronomy and Astrophysics, satisfy most of the major scientific themes outlined for the original SIRTF mission in the "Bahcall Report" (which judged SIRTF the highest priority major new program for all of U.S. astronomy in the 1990s).

SIRTF is optimized to attack the scientific questions listed below. The first four questions identify the four primary science programs of the SIRTF mission. The fifth question identifies the potential for serendipitous discoveries using SIRTF.

1. How do galaxies form and evolve? SIRTF's deep surveys will determine how the number and properties of galaxies changed during the earliest epochs of the Universe.

2. What engine drives the most luminous objects in the Universe? SIRTF will study the evolution with cosmic time of the ultraluminous galaxies and quasar populations and probe their interior regions to study the character of their energy sources.

3. Is the mass of the Galaxy hidden in sub-stellar objects and giant planets? SIRTF will search for cold objects with mass less than 0.08 that of the Sun, not massive enough to ignite nuclear reactions, which may contain a significant fraction of the mass of the Galaxy.

4. Have planetary systems formed around nearby stars? SIRTF will determine the structure and composition of disks of material around nearby stars whose very presence implies that these stars may harbor planetary systems.

5. What lies beyond? SIRTF's greater than 1000-fold gain in astronomical capability beyond that provided by previous infrared facilities gives this mission enormous potential for the discovery of new phenomena.

While these scientific objectives drive the mission design, SIRTF's powerful capabilities have the potential to address a wide range of other astronomical investigations, including studies of the outer solar system, the early stages of star formation, and the origin of chemical elements. Taken together, SIRTF's design capabilities are expected to allow it to achieve many of the initial goals of the Origins program, which are outlined in the Space Science summary section. Moreover, SIRTF's measurements of the density and opaqueness of the dust disks around nearby planets will help set the requirements for future Origins missions designed to directly detect planets.

STRATEGY FOR ACHIEVING GOALS

The Jet Propulsion Laboratory (JPL) was assigned responsibility for managing the SIRTF project. The SIRTF Mission is composed of six major system elements and components as described below. The first three elements (the Science Instruments, Cryo/Telescope Assembly, and Spacecraft Assembly) will be assembled into a single space-based observatory system by means of the fourth element -- System Integration and Test. The fifth element is the launch vehicle, and the sixth is the ground system which will be used to operate the Observatory on the ground prior to launch, and in space to achieve the mission objectives.

Science Instruments will be provided by three Principal Investigators (PIs) selected by NASA in 1984 in response to a NASA Announcement of Opportunity. The three science instruments and their PIs are: the Infrared Array Camera (IRAC), Smithsonian Astrophysical Observatory, Dr. Giovanni Fazio; the Infrared Spectrometer (IRS), Cornell University, Dr. James Houck; and the Multiband Imaging Photometer for SIRTF (MIPS), University of Arizona, Dr. George Rieke.

The Cryo/Telescope Assembly (CTA) will be developed by Ball Aerospace and Technologies Corporation, Boulder, CO, as an industrial member of the SIRTF Integrated Project Team. The CTA will consist of all of the elements of SIRTF that will operate in space at reduced or cryogenic temperatures, including the telescope, telescope cover, cryostat, and supporting structures and baffles. The cryostat will contain the cold portions of the PI-provided Science Instruments.

The Spacecraft Assembly will be developed by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. The spacecraft assembly will consist of all of the elements of SIRTF that are needed for power, data collection, Observatory control and pointing, and communications. These elements of SIRTF are nominally operated at or near 300 degrees Kelvin, and will also include the warm portions of the PI-provided Science Instruments.

System Integration and Test (SIT) has been identified as a separate system element, and will be provided by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. This element will complete the assembly of the Observatory using the science instruments, the CTA, and the Spacecraft Assembly. System level verification and testing, launch preparations and launch of SIRTF will be performed by this element.

Flight and Science and Operations System development will be accomplished in parallel with Observatory development. This will be done to reduce redundant development of ground equipment and software and to assure compatibility between the ground systems and the Observatory after launch. The Flight Operations segment (FOS) will be developed by the mission development team at JPL. The Science Operations Segment (SOS) will be developed by the SIRTF Science Center located at California Institute of Technology's (Cal Tech) Infrared Processing Analysis Center (IPAC).

SIRTF is planned for launch on a Delta 7925-H launch vehicle during FY 2002.

SCHEDULE & OUTPUTS

Start Phase C/D Plan: April 1998 Actual: April 1998	Approved by NASA to proceed with detailed design and development.
Critical Design Review Plan: October 1998 Actual: October 1998	The review at the completion of the detailed design demonstrated that the SIRTF design is credible within planned resources, and that it satisfies the science community's expectations.
Instrument deliveries and performance Plan: April 2000	Deliver the Space Infrared Telescope Facility (SIRTF) Infrared Array Camera (IRAC), Multiband Imaging Photometer (MIPS), and Infrared Spectrograph (IRS) instruments during 4/00. The instruments shall perform at their specified levels at delivery.

ACCOMPLISHMENTS AND PLANS

SIRTF proceeded into detailed design and development phase in 1998. Critical Design Review (CDR) was completed in September 1998. SIRTF will complete its spacecraft bus structure by May 1999. Delivery of all of the focal plane arrays will be completed by September 1999. The flight model of the cryostat will be completed by October 1999. Delivery of the instruments will be completed in FY 2000 to enable integration of the Cryo/Telescope Assembly late in the fiscal year.

BASIS OF FY 2000 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Hubble Space Telescope Development..............................	144,900	161,400	140,400

PROGRAM GOALS

The goal of the Hubble Space Telescope (HST) development activity is to provide new flight hardware, subsystems, and instruments to extend the telescope's operational life and to enhance its prodigious capabilities. The HST was launched in April 1990 aboard the Space Shuttle. It is the first and flagship mission of NASA's Great Observatories program, and it is designed to complement the wavelength capabilities of the other spacecraft in the program (CGRO, AXAF, and SIRTF). The HST is the only one of those observatories that can be serviced and upgraded on orbit. HST is a 2.4-meter telescope capable of performing observations at visible, near-ultraviolet, and near-infrared wavelengths. This program is a joint endeavor of NASA and the European Space Agency (ESA), which provided the faint object camera and the HST's solar arrays. The HST is a general observer facility with a worldwide user community.

STRATEGY FOR ACHIEVING GOALS

HST was designed to be serviceable and requires on-orbit maintenance and replacement of spacecraft subsystems and scientific instruments about every three years. Ongoing modification and upkeep of system ground operations are also performed. HST was designed for a minimum 15-year mission; current plans call for the final servicing mission to occur around 2003, and for the spacecraft to operate beyond that time until around the year 2010 or until it fails.

The mission was troubled soon after launch by the discovery that the primary mirror was spherically aberrated. In addition, problems with the solar panels flexing as the spacecraft passed from the Earth's shadow into sunlight caused problems with the pointing stability. These problems limited HST's capabilities, but it still took observations and generated many scientific discoveries prior to the correction of those problems during the First Servicing Mission in December 1993. That mission included replacement of the solar panels, replacement of the Wide Field and Planetary Camera with a second-generation version with built-in corrective optics, and replacement of the High-Speed Photometer with COSTAR (Corrective Optics Space Telescope Axial Replacement) to correct the aberration for the remaining instruments. The mission was a complete success.

The Second HST Servicing Mission occurred in February 1997. The crew accomplished the following tasks: replaced a failed Fine Guidance Sensor (FGS); swapped one of the reel-to-reel tape recorders with a solid-state recorder; and exchanged two of the original instruments (the Goddard High-Resolution Spectrograph and the Faint Object Spectrograph) with two new instruments, the Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). In addition to this planned work, astronauts discovered that some of the insulation around the light shield portion of the telescope had degraded and they attached several thermal insulation blankets to correct the problem.

The Third HST Servicing Mission, currently scheduled for late FY 2000, will include a full schedule of astronaut activities to upgrade and maintain the observatory. The mission will install a new scientific instrument, the Advanced Camera for Surveys (ACS), as well as a new flight computer and solar arrays. The final servicing mission in 2003 will install the new Cosmic Origins Spectrograph instrument and perform other maintenance activities to ensure that the spacecraft is in excellent health.

SCHEDULE & OUTPUTS

Ship Advanced Camera to GSFC Plan: July 1998 Actual: November 1998	Allows for final testing prior to shipment to the launch site. Late delivery accommodated within schedule for Third Servicing Mission.
HOST/Cryocooler mission Plan: Oct-Nov 1998 Actual: Oct-Nov 1998	Successfully tested hardware to be installed during the Third HST Servicing Mission in FY 2000.
Observatory Upgrades Plan: May 2000	Successfully install and activate three key HST upgrades during the third servicing mission in FY 2000: flight computer, advanced camera, and solar arrays.

ACCOMPLISHMENTS AND PLANS

Planning and hardware development in preparation for the Third HST Servicing Mission is proceeding well. The Advanced Camera for Surveys (ACS) science instrument has been delivered to GSFC, and testing is ongoing. Meanwhile, a Shuttle flight was conducted in October-November 1998 to test various components that will be installed in 2000. Successfully tested were a new cooling system for the NICMOS instrument that should extend NICMOS's operational life by at least five years, as well as a new Solid State Recorder and a new 486-based computer system.

BASIS OF FY 1998 FUNDING REQUIREMENT

RELATIVITY MISSION

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
GP-B Development *	70,800	57,400	40,500
ELV (Non-add)	[13,500]	[14,800]	[14,800]

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Relativity Mission (also known as Gravity Probe-B) is to verify Einstein's theory of general relativity. This is the most accepted theory of gravitation and of the large-scale structure of the Universe. General relativity is a cornerstone of our understanding of the physical world, and consequently of our interpretation of observed phenomena. However, it has only been tested through astronomical observation and Earth-based experiments. An experiment is needed to explore more precisely the predictions of the theory in two areas: (1) a measurement of the "dragging of space" by rotating matter; and (2) a measurement of space-time curvature known as the "geodetic effect". The dragging of space has never been measured, and the geodetic effect needs to be measured more precisely. Whether the experiment confirms or contradicts Einstein's theory, its results will be of the highest scientific importance. The measurements of both the frame dragging and geodetic effects will allow Einstein's Theory to be either rejected or given greater credence. The effect of invalidating Einstein's theory would be profound, and would call for major revisions of our concepts of physics and cosmology.

In addition, the Relativity Mission is contributing to the development of cutting-edge space technologies that are also applicable to future space science missions and transportation systems.

STRATEGY FOR ACHIEVING GOALS

This test of the general theory requires advanced applications in superconductivity, magnetic shielding, precision manufacturing, spacecraft control mechanisms, and cryogenics. The Relativity Mission spacecraft will employ super-precise quartz gyroscopes (small quartz spheres machined to an atomic level of smoothness) coated with a super-thin film of superconducting material (needed to be able to "read-out" changes in the direction of spin of the gyros). The gyros will be encased in an ultra-low magnetic-shielded, supercooled environment (requiring complex hardware consisting of lead-shielding, a dewar containing supercooled helium, and a sophisticated interface among the instrument's telescope, the shielded instrument probe, and the dewar). The system will maintain a level of instantaneous pointing accuracy of 20 milliarcseconds (requiring precise star-tracking, a "drag free" spacecraft control system, and micro-precision thrusters). The combination of these technologies will enable the Relativity Mission to measure: (1) the distortion caused by the movement of the Earth's gravitational field as the Earth rotates west to east; and, (2) the distortion caused by the movement of the Relativity Mission spacecraft through the Earth's gravitational field south to north, to a level of precision of 0.2 milliarcsecond per year (the width of a human hair observed from 50 miles).

The expertise to design, build and test the Relativity Mission, as well as the detailed understanding of the requirements for the dewar and spacecraft, resides at Stanford University in Palo Alto, CA. Consequently, MSFC has assigned responsibility for experiment management, design, and hardware performance to Stanford. Science experiment hardware development (probe, gyros, dewar, etc.) and spacecraft development are conducted at Stanford in collaboration with Lockheed Martin Missiles and Space Palo Alto Research Laboratory (LPARL). Spacecraft development and systems integration will be performed by Lockheed Martin Missiles and Space. Launch is scheduled for October 2000 aboard a Delta II launch vehicle.

SCHEDULE & OUTPUTS

Flight Probe Delivery Plan: September 1997 Current: February, 1998	The flight probe is the interface between the science instrument and the flight dewar. Flight unit delivery will support payload integration. Delay in schedule due to axial lock problem
Flight Probe integrated with Science Instrument Assembly Plan: April 1998 Current: April 1999	Successful integration of the science instrument (comprised of gyroscopes, telescopes, detection electronics, and gas management) with the probe. Schedule delays have resulted from technical problems in various science instruments, subsystems, especially the detector package assembly and acceptance testing of the flight gyroscopes.
Flight Telescope Delivery Plan: February 1998 Current: January 1999	Delivery of the custom, fused-quartz star tracking telescope. Schedule has been delayed principally by numerous development problems with the Detector Package Assembly.
Payload Flight Verification Plan: February 1999 Current: September 1999	Complete the payload (dewar, science instrument, and probe) testing and verification. Schedule delay is driven by later delivery of the science instrument.
Spacecraft Design, Fab, Assy, and Test Plan: March 1999 Current: April 1999	Complete the spacecraft design, fabrication, assembly, and test. Minor delay due to later delivery of some subsystems, including the flight computer, attitude control electronics, and transponder.
Integration and Test Plan: March 2000 Current: September 2000	Complete final integration and test of the Gravity Probe-B science payload. Schedule delay is due to later delivery of the integrated payload as identified above.

Launch
Plan: March 2000
Current: October 2000

Launch aboard a Delta II launch vehicle. The launch date changed back to original date due to delays in the payload subsystems including the probe and the science instrument.

ACCOMPLISHMENTS AND PLANS

The Relativity Mission is proceeding toward the original October 2000 launch date. The program had previously been attempting to achieve an earlier launch date, but technical issues have eliminated that possibility. The spacecraft is manifested to launch aboard a Delta II. Among some of the accomplishment in FY 1998, the Critical Design Review of Payload Electronics was completed in November 1997. The Flight Probe for GP-B was delivered for integration on April 1998 and the flight Superconducting Quantum Interference Device (SQUID) packages were delivered in September 1998.

In FY 1999, the program expects to complete the flight telescope, flight electronics boxes and integrated payload testing.

The program was subject to Independent Annual Review and External Independent Readiness Reviews in 1998 and will support like reviews in 1999 and 2000 leading up to final acceptance and launch.

The delay from the early launch in March 2000 to the baseline date in October 2000 has created the potential for significant cost growth. The cost growth is driven by schedule and manpower needs associated with resolving the technical issues that caused the delay. To prevent or mitigate further schedule delays, resources are being shifted from the spacecraft effort, which is well ahead of critical path, to the science instrument and associated electronics, which are on the critical path. The civil service on-site presence at Stanford has been significantly increased to give greater oversight. NASA is continuing to review Relativity Mission funding requirements and will provide necessary notifications when the final decision is made.

BASIS OF FY 2000 FUNDING REQUIREMENT

THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
TIMED Development *	64,400	49,300	16,000
ELV (Non-add)	[8,700]	[11,500]	[6,100]

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the TIMED mission is to investigate the energetics of the Mesosphere and Lower Thermosphere/Ionosphere (MLTI) region of the Earth's atmosphere (60-180 km altitude). The MLTI is a region of transition in which many important processes change dramatically. It is a region where energetic solar radiation is absorbed, energy input from the aurora maximizes, intense electrical currents flow, and atmospheric waves and tides occur; and yet, this region has never been the subject of a comprehensive, long-term, global investigation. TIMED will provide a core subset of measurements defining the basic states (density, pressure, temperature, winds) of the MLTI region and its thermal balance for the first time. These measurements will be important for developing an understanding of the basic processes involved in the energy distribution of this region and the impact of natural and anthropogenic variations. In a society increasingly dependent upon satellite technology and communications, it is vital to understand the atmospheric variabilities so that the impact of these changes on tracking, spacecraft lifetimes, degradation of materials, and re-entry of piloted vehicles can be predicted. The mesosphere may also show evidence of anthropogenic effects that could herald global-scale environmental changes. TIMED will characterize this region to establish a baseline for future investigations of global change.

STRATEGY FOR ACHIEVING GOALS

The TIMED mission is the first science mission in a planned program of Solar Terrestrial Probes (STP), as detailed in the Space Science Strategic Plan. TIMED is part of NASA's initiative aimed at providing cost-efficient scientific investigations and more frequent access to space. The TIMED mission is scheduled aggressively, but realistically, for a three year development program. TIMED is being developed for NASA by the Johns Hopkins University Applied Physics Laboratory (APL). The Aerospace Corporation, the University of Michigan, NASA's Langley Research Center with the Utah State University's Space Dynamics Laboratory, and the University of Colorado will provide instruments for the TIMED mission.

TIMED is scheduled for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission. The program began its 36-month Phase C/D development period in April 1997. TIMED will be a single spacecraft located in a high-inclination, low-Earth orbit with instrumentation to remotely sense the mesosphere/lower thermosphere/ionosphere regions of the

Earth's atmosphere. TIMED will carry four instruments: the Solar Extreme ultraviolet Experiment (SEE), the Sounding of Atmospheric using Broadband Emission Radiometry (SABER) infrared sounder, the Global Ultraviolet Imager (GUVI) and the TIMED Doppler Interferometer (TIDI).

SCHEDULE & OUTPUTS

Begin Spacecraft I&T Plan: January 1999	Spacecraft integration and test in preparation for launch. On schedule.
Completion of Instrument Development Plan: June 1999	Complete delivery of all 4 flight instruments to APL.
Launch Plan: February 2000 Revised: May 2000	TIMED will be delivered on time for launch, within 10% of the planned development budget.

ACCOMPLISHMENTS AND PLANS

A contract for the TIMED development was awarded in the third quarter of FY 1997 to enable full-scale development of the four instruments and the spacecraft. A Preliminary Design Review (PDR) was held in first quarter of 1997, with a Critical Design Review (CDR) in December 1997. Instrument and spacecraft subsystem fabrication started in FY 1998. The spacecraft structure, harness and Integrated Electronics Module (IEM) engineering model were completed in FY 1998. Spacecraft development will begin in FY 1999, with major components to be integrated and tested. All of the instruments are scheduled for delivery by June 1999. TIMED will be completed in early 2000 and will be in storage until March 2000 with launch scheduled for May 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Stratospheric Observatory for Infrared Astronomy	45,800	58,200	45,100
[Construction of Facilities]	--	[7,300]	--
Total	45,800	58,200	45,100

PROGRAM GOALS

The primary objective of the SOFIA program is to make fundamental scientific discoveries and contribute to our understanding of the universe through gathering and rigorous analysis and distribution of unique infrared astrophysical data. This will be accomplished by extending the range of astrophysical observations significantly beyond that of previous infrared airborne observatories through increases in sensitivity and resolution.

While accomplishing its scientific mission, the SOFIA program will make significant and measurable contributions in meeting national goals for the reform of science, mathematics, and technology education, particularly at the K-16 level, and in the general elevation of scientific and technological literacy throughout the country. In addition, the SOFIA program will identify, develop, and infuse promising new technologies, which will enable or enhance scientific or educational objectives and reduce mission life-cycle costs.

STRATEGY FOR ACHIEVING GOALS

Astronomical research with instrumented jet aircraft has been an integral part of the NASA Physics and Astronomy program since 1965. For relatively low cost, NASA has been able to provide to the science community very quick, global response to astronomical "targets of opportunity." The Stratospheric Observatory For Infrared Astronomy (SOFIA) is a new airborne observatory designed to replace the retired Kuiper Airborne Observatory (KAO). SOFIA consists of a 2.5 m telescope provided by the German Aerospace Center (DLR) integrated into a modified Boeing 747 aircraft. With spatial resolution and sensitivity far superior to the KAO, SOFIA will facilitate significant advances in the study of a wide variety of astronomical objects, including regions of star and planet formation in the Milky Way, activity in the nucleus of the Milky Way, and planets, moons, asteroids and comets in our solar system. The program will build upon a very successful program of flying teachers on the KAO by using SOFIA to reach out to K-12 teachers as well as science museums and planetaria around the country.

KAO operations were terminated in October 1995; the savings from cessation of KAO operations are an integral element of the funding plan for SOFIA. Development of SOFIA started in FY 1997. In December 1996, NASA selected a team led by the Universities

Space Research Association (USRA), Columbia, MD, to acquire, develop and operate SOFIA. The Cost-Plus-Incentive and Award Fee-type contract has a base period for development plus one five-year operations cycle. The contract also contains an option period for one additional five-year operations cycle. SOFIA is expected to operate for at least 20 years. The contract is managed by NASA's Ames Research Center, Mountain View, CA. Other team members include Raytheon Systems Company - Waco, TX ; United Airlines, San Francisco; an alliance of the Astronomical Society of the Pacific and The SETI Institute, both of Mountain View, CA; Sterling Software, Redwood City, CA; and the University of California at Berkeley and Los Angeles. The contract calls for the selected company to acquire an existing Boeing 747 SP aircraft, design and implement a modification program to accommodate installation of a large infrared telescope (provided by Germany), test and deliver the flying astronomical observatory to NASA, and provide mission and operations support in approximately five-year increments. USRA's proposal calls for operating the aircraft out of Moffett Federal Airfield, Mountain View, CA, with initial operations starting October 2001. SOFIA funding includes $7.3 million in FY 1999 Construction of Facilities funds for modification of SOFIA ground support facilities at Ames Research Center.

SCHEDULE & OUTPUTS

US System Preliminary Design Review Plan: August 1998 Actual: November 1998	Review of the U.S. contractor's concept for development and integration of the observatory. Slipped due to delays in the development of the German telescope assembly.
Telescope Assembly Critical Design Review Plan: November 1998 Revised: Spring 1999	Formal review of the German contractor's concept for implementation of the telescope assembly. Slipped due to delays in the development of the German telescope assembly.
US System Critical Design Review Plan: September 1999	Formal review of the US concept for implementation of the observatory. NOTE: Planned dates of implementation for this and subsequent milestones are under review as a result of the delay expected in the delivery of the German telescope assembly.
Complete mockup test activity Plan: June 2000	Complete the 747 Section 46 mockup test activity with no functional test discrepancies that would invalidate CDR-level designs and cause significant design rework with attendant cost and schedule impact.

ACCOMPLISHMENTS AND PLANS

The 747 SP aircraft for SOFIA was purchased in early 1997 and is now at the contractor facility in Waco. It has been completely stripped out and undergone a thorough inspection prior to the extensive modification and integration program required to accommodate the German Telescope Assembly.

In FY 1998, the 747 SP aircraft was instrumented and flown from the Waco facility during its baseline flight test phase in order to determine its exact structural and aerodynamic parameters, in addition to the handling characteristics of this specific aircraft, prior to its entering the modification program. This data was also used extensively to validate the wind tunnel and computational aerodynamic models and algorithms during wind tunnel tests at NASA's Ames Research Center at Moffett Field, CA in FY 1998.

Also in FY 1998, a large section of the aft fuselage from a surplus 747 SP was acquired and delivered to Waco via the NASA "SuperGuppy" cargo aircraft to Waco. The section has begun a modification program to serve as a pathfinder to validate the detailed design, fabrication, and integration processes to be used on the SOFIA aircraft.

In Germany, the primary mirror (2.5-meter effective diameter) began an extensive light-weighting process, whereby cells are delicately machined to remove mass from the substrate of the mirror without compromising its precision surface. About three-quarters of the planned mass was removed during the year, on schedule.

Early in FY 1998, the dates for completion of both the German and U.S. preliminary design reviews (PDRs) were delayed from the baseline plans due to unanticipated technical challenges that surfaced for the German Telescope Assembly contractors. These telescope delays affected aircraft-telescope interface design completion, and had a similar delay on the U.S. effort. However, both the U.S. and German PDRs were subsequently held and successfully completed (in early FY 1999) for their respective contributions to this cooperative program.

In FY 1999, as noted above, the U.S. and German PDRs have been completed, and plans are underway to accomplish the Telescope Assembly Critical Design Review (CDR) later in this year. Fabrication and initial integration of key core telescope subsystems will also take place. A major task in FY 1999 will be to re-plan the overall program, to preserve efficiency and recognize the delay in the planned delivery of the German telescope. Also, in FY 1999, modifications of the hangar at Moffett Field, CA will begin, ultimately leading to the Science and Mission Operations Center, the "home" for the SOFIA Observatory once it enters science operations. Finally, wind tunnel testing and aerodynamic analysis of the modified aircraft will be completed.

In FY 2000, subject to details to be worked out as a part of the re-planning mentioned above, it is anticipated that the U.S. systems CDR will be completed, the fuselage section mockup pathfinder work will be completed, and major aspects of the structural modification of the 747 SP will be underway. Our German partners should also be far along in the fabrication and integration of the Telescope Assembly, building up to its delivery to the U.S. in the following year (FY 2001) for integration into the SOFIA aircraft.

BASIS OF FY 2000 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Astro-E	7,100	6,400	
Rosetta	[4,900]	12,500	6,200
Cluster-II	3,300	5,000	1,000
Shuttle/international payloads	7,600	5,000	2,800
Total	18,000	28,900	10,000

PROGRAM GOALS

Payload and Instrument Development supports development of hardware to be used on international satellites or on Shuttle missions. International collaborative programs offer opportunities to leverage U.S. investments, obtaining scientific data at a relatively low cost. Shuttle missions utilize the unique capabilities of the Shuttle to perform scientific experiments that do not require the extended operations provided by free-flying spacecraft. Payload and Instrument Development supports investigations in the Sun-Earth Connections, Structure and Evolution of the Universe, and Exploration of the Solar System science themes.

STRATEGY FOR ACHIEVING GOALS

In the FY 1994 appropriation, Congress directed NASA to pursue flight of a GSFC-developed X-ray spectrometer on the Japanese Astro-E mission. NASA will contribute improved foil mirrors and an X-ray calorimeter derived from the spectrometer previously planned for the canceled AXAF-S mission. This new device will measure the energy of an incoming X-ray photon by precisely measuring the increase in temperature of the detector as the photon is absorbed. It will provide high quantum efficiency over a large instantaneous bandpass, from 0.3 to 10 keV, at an unprecedented spectral resolution of approximately 15 eV over the entire bandpass. The foil mirrors will have a large collecting area, approximately 400 square centimeters at 6 keV, and will provide approximately 2 arc second resolution. These capabilities will permit an unprecedented sensitivity study of a wide range of astrophysical sources, answer many outstanding questions in astrophysics, and likely pose many new ones. Launch is scheduled for February 2000.

The European Space Agency's ROSETTA mission is a cometary mission that will be launched in the year 2003 by an Ariane 5. After a long cruise phase, the satellite will rendezvous with comet Wirtanen and orbit it, while taking scientific measurements. During the cruise phase, the satellite will be given gravity assist maneuvers once by Mars and twice by the Earth. The satellite will also take measurements in fly-bys of two asteroids. U.S involvement in the Rosetta program includes the development of three remote sensing instruments, as well as support for interdisciplinary scientists and a number of U.S. co-investigators.

The original Cluster mission, part of the International Solar-Terrestrial Physics program, was lost on June 4, 1996 with the explosion of the Ariane-5 rocket. Reflight of the full mission (Cluster-II) has been approved by the European Space Agency and NASA. The four spacecraft will carry out three-dimensional measurements in the Earth's magnetosphere, covering both large- and small-scale phenomena in the sunward and tail regions. Launch is scheduled for June 2000 on two Soyuz vehicles.

The Shuttle/International Payloads program supports other international and U.S. development projects, including portions of two instruments to be flown on Europe's X-ray Mirror Mission (XMM, 1999); and participation in Europe's International Gamma Ray Astrophysics Laboratory (INTEGRAL, 2001) and Planck missions.

The ESA XMM satellite will have highly sensitive instruments providing broad-band study of the X-ray spectrum. This mission will combine telescopes with grazing incidence mirrors and a focal length greater than 7.5 meters with three imaging array instruments and two Reflection Grating Spectrometers (RGS). The U.S. is providing components to the Optical Monitor (OM) and RGS instruments. XMM science will be complementary to the U.S. Advanced X-ray Astrophysics Facility (AXAF). XMM's higher through-put (i.e., higher number of photons collected) will allow somewhat better spectroscopy of faint sources, while AXAF will excel at high resolution imaging. XMM is scheduled for launch in August 1999 on an Ariane V vehicle, and has an operational lifetime goal of 10 years.

The ESA INTEGRAL mission will perform detailed follow-on spectroscopic and imaging studies of objects initially explored by the Compton Gamma Ray Observatory. Its enhanced spectral resolution and spatial resolution in the nuclear line region will provide a unique channel for the investigation of processes -- nuclear transitions, electron/positron annihilation, and cyclotron emission/absorption -- taking place under extreme conditions of density, temperature, and magnetic field. U.S. participation consists of co-investigators providing hardware and software components to the spectrometer and imager instruments; a co-investigator for the data center; a mission scientist; and a provision for ground tracking and data collection. Launch is expected in March 2001; INTEGRAL has a design life of two years.

Planck is the third Medium-Sized Mission (M3) of ESA's Horizon 2000 Scientific Programme. It is designed to image the anisotropies of the Cosmic Background Radiation Field over the whole sky, with unprecedented sensitivity and angular resolution. Planck will provide a major source of information to help resolve several cosmological and astrophysical issues by verifying or refuting the assumptions underlying competing theories of the early universe and the origin of cosmic structure. Although formal agreements have not been finalized, NASA expects to contribute hardware elements for the mission in exchange for science participation.

SCHEDULE & OUTPUTS

Astro-E:

Flight model spectrometer delivery to Japan
Plan: July 1997
Revised: February 1999

This task concludes the XRS instrument construction phase and begins a period of validation, testing and calibration. Expected to be completed late, with subcomponents delivered to Japan as completed. Late deliveries have been accommodated by the Japanese within their schedule.

Final mirror quadrant delivery Plan: December 1998 Revised: February 1999	Satisfies NASA's commitment to provide the X-ray mirrors for the mission to Japan. Late deliveries have been accommodated by the Japanese within their schedule.
Rosetta: Start Phase C/D Plan: January 1999	Start of detailed design and fabrication.
Qual model deliveries Plan: May 2000	The Rosetta project will deliver the electrical qualification models for the four U.S.- provided instruments to ESA in 5/00 for integration with the Rosetta Orbiter.
Cluster-II: First flight model instrument set delivered Plan: September 1998 Actual: September 1998	The U.S will provide an identical set of instrument hardware for each of the four Cluster-II spacecraft.
4th/final flight model instrument set delivered Plan: August 1999	On schedule.
Instrument Analysis Software and Verification Plan: FY 2000	Complete development of Cluster-II instrument analysis software for the one U.S. and five U.S.-partnered instruments before launch and, if launch occurs in FY00, activate and verify the Wideband Data (WBD) and U.S. subcomponents after launch.
Other Shuttle/International: XMM: deliver RGS FM-2 components Plan: May 1998 Actual: March 1998	Delivery of U.S. Reflection Grating Spectrometer Flight Model-2 components to Germany for calibration testing with the X-ray telescope.
XMM Launch Plan: August 1999 Revised: January 2000	Launch on Ariane-5 ELV. Later launch date set by the Europeans for reasons unrelated to U.S. hardware deliveries.
INTEGRAL Critical Design Review Plan: June 1999	This ESTEC/ESA program review will include the U.S.-provided hardware. On schedule.

INTEGRAL operations readiness Plan: FY 2000	Prepare the INTEGRAL Science Data Center (ISDC) for data archiving and prepare instrument analysis software for Spectrometer on INTEGRAL (SPI) instrument within 10% of estimated cost.
Planck cooler test Plan: April 2000	Assemble and successfully test the breadboard cooler for ESA's Planck mission

ACCOMPLISHMENTS AND PLANS

The first quadrant of flight model mirrors for Astro-E was delivered to Japan in December 1997, and the fifth and final mirror will be delivered by February 1999, about two months late. The science instrument hardware has experienced even more serious technical difficulties and delays, resulting in a slight overrun (about 3% to date). The project is still on schedule for a February 2000 launch, but is being threatened by late deliveries of U.S. hardware, which have already required the Japanese to modify their schedule significantly. We will continue to work with our Japanese partners to ensure a successful mission.

Phase C/D development of the U.S. Rosetta instruments will begin in January 1999. Thermal qualification models will be delivered in April 1999, followed by electrical qualification models in February 2000.

Cluster II instrument development activities have progressed very well. Deliveries of the 2nd, 3rd, and 4th Cluster-II flight model sets will occur throughout FY 1999, supporting ESA's June 2000 launch date.

XMM Flight Model-2 RGS components were delivered to Germany ahead of schedule in March 1998. The U.S. will support integration of instruments onto the spacecraft, and spacecraft integration with the launch vehicle, up through planned launch in January 2000.

INTEGRAL engineering model instruments were delivered to ESTEC on schedule in May 1998. Work on the flight model will continue through FY 99; Flight Model delivery is expected in October 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

EXPLORER PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
FUSE	38,100	15,900	--
SWAS, TRACE, WIRE	28,700	6,500	--
IMAGE & MAP	65,200	82,300	42,300
STEDI (SNOE, TERRIER, CATSAT)	1,200	5,500	1,000
HETE-II	7,500	7,200	--
Explorer Planning (All Others)	28,600	78,600	107,700
ELV (Non-add)	[55,800]	[81,700]	[45,800]
*Total	169,300	196,000	151,000

*Total cost information is provided in the Special Issues section.

PROGRAM GOALS

The goal of the Explorer Program is to provide frequent, low-cost access to space for Space Science investigations that can be accommodated with small to mid-sized spacecraft. The program supports investigations in all Space Science disciplines. Investigations selected for Explorer projects are usually of a survey nature, or have specific objectives not requiring the capabilities of a major observatory. The Explorer Program continues to seek reductions in the cost of developing spacecraft, in order to provide more frequent launch opportunities for Space Science missions.

STRATEGY FOR ACHIEVING GOALS

Explorer mission development is managed within an essentially level funding profile. New missions are therefore subject to the availability of sufficient funding in order to stay within the total program budget. Explorer missions are categorized by size, starting with the largest, Delta-class, moving down through the Medium-class (MIDEX), the Small-class (SMEX) and the University-class (UNEX) missions. As part of NASA's efforts to reduce the cost of Explorer missions, no new Delta-class missions are budgeted. Funding for Explorer mission studies is also provided within the Explorer budget.

Delta Class

Development of the Far Ultraviolet Spectroscopy Explorer (FUSE) began early in FY 1996. The FUSE mission, previously planned as a Delta-class mission, was restructured in order to reduce costs and accelerate the launch date from CY 2000 to early CY 1999.

Although not a MIDEX mission, FUSE can be seen as a transitional step towards the MIDEX program. FUSE will conduct high-resolution spectroscopy in the far ultraviolet region. Major participants include the Johns Hopkins University, the University of Colorado, and University of California, Berkeley. Orbital Sciences Corporation was selected by JHU as the spacecraft developer. Canada provides the fine error sensor assembly, and France provides holographic gratings. GSFC provides management oversight of this Principal Investigator-managed mission.

Medium Class

The Medium-class Explorer (MIDEX) program was initiated to facilitate more frequent flights, and thus more research opportunities, in all OSS themes. Plans call for about one MIDEX mission to be launched per year, with life-cycle cost capped at no more than $140 million (FY1998 dollars) each, including the cost of the launch vehicle and mission operations and data analysis.

In March 1996 NASA selected the first two science missions for the MIDEX program, the Microwave Anisotropy Probe (MAP) and the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE). The MAP Mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos. GSFC is developing the MAP instruments in cooperation with Princeton University. MAP is scheduled for launch in November 2000.

The IMAGE mission will use three-dimensional imaging techniques to study the global response of the Earth's magnetosphere to variations in the solar wind, the stream of electrified particles flowing out from the Sun. The magnetosphere is the region surrounding the Earth controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. Southwest Research Institute is developing the IMAGE mission for launch in February 2000. The Announcement of Opportunity (AO) for MIDEX 3 & 4 was released in April of 1998 and selections will be made in early CY 1999.

Small Class

The Small Explorer (SMEX) program provides frequent flight opportunities for highly focused and relatively inexpensive missions. Each SMEX mission is expected to cost no more than $71 million (in FY 1998 dollars) for design, development, launch vehicle and operations. The Explorer Program Office at the Goddard Space Flight Center (GSFC) manages mission definition, development, and launch of these SMEX missions.

The Transition Region and Coronal Explorer (TRACE) mission initiated development in October 1994, and was successfully launched in April 1998. TRACE is a solar science mission that will explore the connections between fine-scale magnetic fields and their associated plasma structures. Observations of solar-surface magnetic fields will be combined with observations showing their effects in the photosphere, chromosphere, transition region and corona. Major participants include the Lockheed Palo Alto Research Laboratory and the Harvard-Smithsonian Center for Astrophysics.

The Submillimeter Wave Astronomy Satellite (SWAS) mission initiated development in 1991. SWAS will provide discrete spectral data for study of the water, molecular oxygen, neutral carbon, and carbon monoxide in dense interstellar clouds, the presence of which is related to the formation of stars. Major participants include the Smithsonian Astrophysical Observatory, the Millitech Corporation, Ball Aerospace, and the University of Cologne, which provided a spectrometer. The launch of the SWAS mission was delayed from January 1997 to December 1998 due to failures of the Orbital Sciences Corporation (OSC) Pegasus launch vehicle and subsequent Pegasus manifest problems. SWAS was successfully launched in December 1998.

The Wide-field Infrared Explorer (WIRE) mission initiated development in October 1994, and is scheduled for launch in early CY 1999. WIRE will detect starburst galaxies, ultraluminous galaxies, and luminous protogalaxies. Major participants in WIRE include Utah State University, Ball Aerospace, Cornell University, California Institute of Technology, and the Jet Propulsion Laboratory.

NASA released a SMEX Announcement of Opportunity (AO) in 1997, and selected the High Energy Solar Spectroscopic Imager (HESSI), being developed by the University of California at Berkeley, and the Galaxy Evolution Explorer (GALEX), being developed by the California Institute of Technology, to be the next Small Explorer missions. HESSI will observe the Sun to study particle acceleration and energy release in solar flares. GALEX will use an ultraviolet telescope during its two-year mission to explore the origin and evolution of galaxies and the origins of stars and heavy elements. GALEX will detect millions of galaxies out to a distance of billions of light years, and will also conduct an all-sky ultraviolet survey. HESSI is scheduled for launch on board a Pegasus ELV in the summer of 2000. GALEX is scheduled for launch in mid-CY 2001.

University Class

University-class Explorer (UNEX) missions enable a higher flight rate to provide the academic community with routine access to space science research. UNEX are very small, low-cost missions managed, designed and developed at universities in cooperation with industry. The program will develop greater technical expertise within the academic community beyond the suborbital class missions currently being flown aboard balloons and sounding rockets, thus creating greater opportunity for students and reducing the required role of NASA in-house expertise. NASA released a UNEX AO in 1998 and selected two new missions, CHIPS and IMEX.

The Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) spacecraft to be developed by the University of California Berkeley, will use an extreme ultraviolet spectrograph during its one-year mission to study the "Local Bubble," a tenuous cloud of hot gas surrounding our Solar System that extends about 300 light-years from the Sun.

The second mission, the Inner Magnetosphere Explorer (IMEX), to be developed by the University of Minnesota, will study the response of Earth's Van Allen radiation belts to variations in the solar wind. Future UNEX missions will be capped at $7.5 million in real year dollars for definition, development, launch, operations and data analysis.

The UNEX missions under the Student Explorer Demonstration Initiative (STEDI) include the Student Nitric Oxide Experiment (SNOE), launched in January 1998; the Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS), scheduled for launch during the 2nd Qtr of CY 1999; and the Cooperative Astrophysics and Technology Satellite (CATSAT), with launch expected in 2001.

MISSIONS OF OPPORTUNITY

The Missions of Opportunity (MOpp) were instituted within the Explorer Program as part of the previously mentioned SMEX AO. MOpp are space science investigations, costing no more than $21 million in FY1998 dollars, that are flown as part of a non-NASA space mission. MOpp are conducted on a no exchange of funds basis with the organization sponsoring the mission. OSS intends to solicit proposals for MOpp with all future Explorer AOs. Under the 1997 SMEX AO, the Two Wide-Angle Neutral-Atom Spectrometers (TWINS) investigation was selected as a MOpp. TWINS will enable three-dimensional global visualization of Earth's magnetospheric region, thereby greatly enhancing understanding of the connections between different regions of the magnetosphere and their relation to the solar wind. Instruments for the TWINS mission are being developed by Los Alamos National Laboratory (LANL).

HETE-II

Development is underway for HETE-II, an international (France, Italy and Japan) collaboration to be launched in late 1999. HETE-II will seek to obtain precise positions of gamma-ray bursters and other high-energy transient sources. HETE-II is a replacement for HETE-I, which was launched 100 miles off the coast of Wallops Island, Virginia, on November 4, 1996, but was lost due to launch vehicle third-stage power failures.

SCHEDULE & OUTPUTS

Far Ultraviolet Spectroscopy Explorer (FUSE)

Integration & Test Plan: April 1998 Actual: December 1998	Assemble and test major spacecraft components. Integration completed in August; testing completed December 1998. Late deliveries of several components, particularly the Fine Error Sensors, caused these delays.
Ship to KSC Plan: September 1998 Current: April 1999	Complete spacecraft system-level testing successfully. Move to KSC for integration with Delta II launch vehicle. Slipped due to component I&T problems noted above, and gyro test results suggesting potential lifetime issue, necessitating gyro rework and additional testing.
Launch **Plan: October 1998** **Current: May 1999**	Development delays noted above.

Medium-class Explorer Program

<u>IMAGE</u> Complete S/C Environmental Testing Plan: April 1999	Integrate and test major spacecraft subsystems. On schedule.
Delivery, Launch, Cost Plan: February 2000	IMAGE will be delivered for an on-time launch within 10% of the planned development budget.
<u>MAP</u> Instrument Delivery Plan: 2nd Qtr. CY 1999	Complete instrument development and ship for integration with the spacecraft. On schedule.
Begin S/C I&T Plan: 3rd Qtr. CY 1999 Actual:	Integrate and test major spacecraft components. On schedule.
Start Environmental Testing Plan: July 2000	Begin system-level environmental testing of the spacecraft.

Small-class Explorer Program

<u>SWAS</u> Launch Plan: March 1997 Actual: December 1998	Delayed due to Pegasus launch vehicle availability.
<u>TRACE</u> Launch Plan: October 1997 Actual: March 1998	Delayed due to Pegasus launch vehicle availability.
<u>WIRE</u> Launch Plan: August 1998 Current: March 1999	Delayed due to Pegasus launch vehicle availability.

HESSI
Delivery, Launch, Cost
Plan: July 2000

The High Energy Solar Spectroscopic Imager will be delivered for an on-time launch, within 10% of the planned development budget.

GALEX
Instrument delivery
Plan: July 2000

Deliver the Galaxy Evolution Explorer Science Instrument from JPL to the Space Astrophysics Laboratory at Caltech for science calibration. The instrument will be fully integrated, functionally tested, and environmentally qualified at the time of delivery.

TWINS
Component deliveries
Plan: March 2000

Deliver to the Los Alamos National Laboratory (LANL) all components for system integration and testing of the first flight system for the Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) mission.

University-class Explorer Program

SNOE
Launched
Actual: January 22, 1998

Completed development and launched spacecraft into orbit. Spacecraft is performing well.

TERRIERS
Launch
Plan: April 1999

Begin the study a number of ionospheric and thermospheric phenomena, and test the utility of long term solar EUV (extreme ultraviolet) irradiance measurements.

CATSAT
Launch
Plan: 3rd Qtr FY 1999
Revised: TBD

Complete development and launch spacecraft into orbit. Delayed due to uncertain launch accommodations.

HETE-II
Launch
Plan: December 1999

Complete development and launch spacecraft into orbit on an Ultra-Lite Class ELV (half Pegasus). On schedule.

AO Activities

Release of UNEX AO Plan: 2nd Qtr FY 1997 Actual: January 1998	Release an Announcement of Opportunity (AO) for the first round of UNEX missions. Delayed in getting inputs from industry/potential bidders, and implementing lessons learned from the SMEX and MIDEX AO.
Release MIDEX AO Plan: 4th Qtr. FY 1998 Actual: March 1998	Release AO to industry.
Complete UNEX selection Plan: 4th Qtr FY 1997 Actual: September 1998	Select the first round of UNEX missions and initiate development activities. Delayed with delayed release of AO.
MIDEX Selection Plan: 4th Qtr. FY 1999 Actual: January 1999	Mission selection, and initiate concept studies.
Release SMEX AO to industry Plan: 3rd Qtr FY 1999	Release the final AO to industry. On schedule.
SMEX AO Selection Plan: 1st Qtr FY 2000	Missions selection, leading to concept studies.
FY 2000 goals	Select two Small Explorer (SMEX) missions and release a University Explorer (UNEX) Announcement of Opportunity (AO).

ACCOMPLISHMENTS AND PLANS

The Explorers Program successfully launched two missions during FY 1998. The Student Explorer Demonstration Initiative (STEDI) launched the Student Nitric Oxide Explorer (SNOE) in January and the SMEX Project launched the Transition Region and Coronal Explorer (TRACE) in April. The FUSE observatory finished integration and entered its critical environmental test program. Spacecraft component and instrument development continued on the IMAGE and MAP projects. The AO for MIDEX's 3 and 4 was released in April. Testing was completed on the SMEX project's SWAS and WIRE missions. Also the HESSI and GALEX missions were selected. The TWINS mission was selected as a Mission of Opportunity (MOpp). The STEDI missions; TERRIERS and CATSAT continued development. The AO for UNEX 1 and 2 was released and the CHIPS and IMEX missions were selected. Their concept studies are underway. The Polarimeter for Low Energy X-ray Astrophysical Sources (PLEXAS) was also selected under this AO as a technology initiative at the Harvard-Smithsonian Center for Astrophysics.

The Explorers Program is planning to launch four missions in FY 1999. The SWAS mission was successfully launched in December 1998. The WIRE, TERRIERS, and FUSE missions are scheduled for launch in February, April and May, respectively. Development continues on the IMAGE, MAP, HESSI, GALEX, CHIPS, and IMEX missions. Also four MIDEX's will be selected for Phase A studies which will lead to the down-selection of two new MIDEX missions for developments during the latter part of the fiscal year.

The FY2000 Explorers budget continues to support a full range of mission activities across the various classes of missions. MIDEX activities will include the IMAGE launch scheduled for February 2000. MAP will complete system-level testing and be ready for the November 2000 scheduled launch. Two new MIDEX missions, selected in FY 1999, are expected to complete the formulation phase and enter into development. SMEX activities include the HESSI launch, scheduled for July 2000, and the GALEX science instrument delivery from Jet Propulsion Laboratory (JPL) to the California Institute of Technology. Two new SMEX missions will be selected. The University-class Explorer (UNEX) budget will support the continued development of the CHIPS and IMEX missions, and the launch and early operations of the Cooperative Astrophysics and Technology Satellite (CATSAT). Funding will also be provided to continue MO&DA activities for the SNOE and Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS) missions. Development will continue on the two missions to be selected in FY 1999. Missions of Opportunity (MOpp) include a launch for High Energy Transient Explorer (HETE)-II and continued development of the Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS) mission. Potential new MOpps selected through current or FY 1999 AOs will also be supported.

BASIS OF FY 2000 FUNDING REQUIREMENT

DISCOVERY PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Lunar Prospector *	400	--	--
Stardust *	56,200	22,300	--
Genesis *	29,900	82,900	50,200
CONTOUR *	--	--	51,800
Future Missions	13,500	19,700	78,500
ELV (Non-add)	[23,500]	[30,300]	[42,900]
Total	100,000	124,900	180,500

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The Discovery program provides frequent access to space for small planetary missions that will perform high-quality scientific investigations. The program responds to the need for low-cost planetary missions with short development schedules. Emphasis is placed on increased management of the missions by principal investigators. The Discovery program is intended to accomplish its missions while enhancing the U.S. return on its investment and aiding in the national goal to transfer technology to the private sector. It seeks to reduce total mission/life cycle costs and improve performance by using new technology and by controlling design/development and operations costs. A Discovery mission development cost (Phase C/D through launch plus 30 days) must not exceed $150 million (FY 1992 dollars), and the mission must launch within 3 years from start of development. The program also seeks to enhance public awareness of, and appreciation for, space exploration and to provide educational opportunities.

STRATEGY FOR ACHIEVING GOALS

The Lunar Prospector mission was selected as the third Discovery mission in FY 1995 with mission management from the NASA Ames Research Center. The spacecraft was launched successfully on January 6, 1998. Lockheed Martin supplied the launch, spacecraft and instruments, and is providing operations support. Tracking and communications support is supplied by the Deep Space Network. The mission is designed to search for resources on the Moon, with special emphasis on the search for water in the shaded polar regions.

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory, and was approved for implementation in October, 1996. The mission is designed to gather samples of dust from the comet Wild-2 and return the samples to Earth for detailed analysis. Stardust will also gather and return samples of interstellar dust that the spacecraft encounters during its trip through the Solar System to fly by the comet. Stardust will use a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, Stardust will carry three additional scientific instruments. An optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) is provided by Germany to perform basic compositional analysis of the samples while in flight; and a dust flux monitor will be used to sense particle impacts on the spacecraft. Stardust will be launched on a Med-Lite version of the Delta II expendable launch vehicle in February 1999, to rendezvous with the comet in January 2004 and return the samples to Earth in January 2006.

In October 1997 NASA selected the next two Discovery missions: Genesis and the Comet Nucleus Tour (CONTOUR). The Genesis mission is designed to collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis. The mission is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA. JPL will provide the payload and project management, while the spacecraft will be provided by Lockheed Martin Astronautics of Denver, CO. Due for launch in January 2001, Genesis will return the samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert in August 2003. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud.

CONTOUR's goals are to dramatically improve our knowledge of key characteristics of comet nuclei and to assess their diversity. The spacecraft will leave Earth orbit, but stay relatively near Earth while intercepting at least three comets. The targets span the range from a very evolved comet (Encke) to a future "new" comet such as Hale-Bopp. CONTOUR builds on the exploratory results from the Halley flybys, and will extend the applicability of data obtained by NASA's Stardust and ESA's Rosetta to broaden our understanding of comets. The Principal Investigator is J. Veverka of Cornell University; the spacecraft and project management will be provided by the Johns Hopkins University Applied Physics Laboratory of Laurel, MD. Launch is expected in June 2002.

Total Discovery mission development is managed within an approved funding profile. New mission starts are therefore subject to availability of sufficient funding in order to stay within the total program budget. Funding for mission studies is also provided within the Discovery Future Missions budget.

SCHEDULE & OUTPUTS

Stardust

Start Spacecraft Assembly/Test Plan: January 1998 Actual: January 1998	Begin to integrate major components of the spacecraft onto the spacecraft structure.
Start environmental tests Plan: June 1998 Actual: July 1998	Begin tests to demonstrate that the assembled spacecraft can withstand the launch and space environments. Started slightly late; no impact to launch – spacecraft shipped on schedule to KSC November 11.

Launch Plan: February 1999	On schedule.
Genesis	
Preliminary Design Review Plan: August 1998 Actual: July 1998	Confirmation that the mission is ready to proceed to Phase C/D.
Critical Design Review Plan: May 1999	Confirmation that the mission design is sound. On schedule.
Start functional testing Plan: November 1999	Complete Genesis spacecraft assembly and start functional testing in 11/99.
CONTOUR	
Phase B Study Start Plan: October 1998 Revised: April 1999	Start of detailed design studies. Revision does not impact launch schedule.
Instrument and Spacecraft Development Plan: FY 2000	Successfully complete the bread-board of the imager instrument for CONTOUR and award the contract for the propulsion system after a PDR that confirms the design and maintains 15% margins for mass and power.
Announcements of Opportunity (AOs)	
Release Final AO Plan: 3rd Qtr FY 1998 Actual: March 1998	Release an Announcement of Opportunity (AO) for the next discovery mission(s). Completed ahead of schedule.
Step 2 Selection Plan: 3rd Qtr FY 1999	Phase 2 selection leading to Phase B studies. On schedule.
FY 2000 Goal	Release an AO for the next Discovery mission.

ACCOMPLISHMENTS AND PLANS

Assembly and test of the Stardust spacecraft components was completed on time, and the spacecraft was shipped to KSC in preparation for launch in February 1999.

The Genesis mission is off to a fast start, as required to meet its planned launch in January 2001. Phase C/D activities began in August 1998, following completion of the Preliminary Design Review. During FY 1999, detailed design activities will continue, leading to the Critical Design Review in May 1999. System level integration and test activities will occur during FY 2000

The CONTOUR mission will start Phase B in FY 1999. The mission plans for twelve months of Phase B studies, followed by the start of Phase C/D development early in FY 2000.

A draft Announcement of Opportunity was released for comment in January 1998, and the final AO was released in March 1998. In November 1998, five candidate Discovery missions were selected for further study, including missions to Mercury, Venus, Mars, Jupiter, and a comet. Also selected for development was a proposal to build hardware for the European Space Agency's Mars Express mission, which will fly in 2003. Final proposals will be submitted in March, leading to selection of the next Discovery mission(s) this summer.

BASIS OF FY 2000 FUNDING REQUIREMENT

MARS SURVEYOR PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
98 Orbiter and Lander	79,600	22,000	--
01 Orbiter and Lander	71,200	150,700	126,800
Mars Network	--	--	4,100
Micromissions	--	--	5,000
Future Missions	37,100	55,700	114,800
ELV (Non-add)	[42,700]	[48,700]	[40,900]
Total	187,900	228,400	250,700

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the Mars Surveyor Program is to further our understanding of the biological potential and possible biological history of Mars, and to search for indicators of past and/or present life there. The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. Missions are planned for launch at every launch opportunity; opportunities occur about every 26 months due to the orbital periods of Earth and Mars. In the near term, missions may either orbit Mars to perform mapping of the planet and its space environment, or actually land on the planet to perform science from the surface. A long-term goal is to acquire and return the first carefully selected sample cache by 2008 and at least three sets of samples from diverse sites by 2012. Earlier missions will facilitate this long-range goal by identifying those areas of Mars most likely to contain samples of scientific importance, including (potentially) evidence of past biological activity.

STRATEGY FOR ACHIEVING GOALS

This program began in FY 1994 with the development of the Mars Global Surveyor, an orbiter that will obtain much of the data that would have been obtained from the Mars Observer mission. The orbiter carries a science payload, comprised of 6 of 8 spare Mars Observer instruments, aboard a small, industry-developed spacecraft. MGS was launched in November 1996 aboard a Delta II launch vehicle and placed on a trajectory to Mars. The spacecraft arrived at Mars in September 1997. The spacecraft will use aerobraking to arrive at its final mapping orbit in January 1999, and full mapping operations will begin in March 1999. This mission is to be succeeded by a series of small orbiters and landers, which will make in-situ measurements of the Martian climate and soil composition. Technology developed by the Mars Pathfinder mission will be optimized to reduce lander mission costs and technical risk. The Mars Climate Orbiter successfully launched in December 1998, and the Mars Polar Lander successfully launched in January 1999. These missions will be followed by two launches in the March/April 2001 opportunity, and launches in the 2003 and 2005 opportunities.

The 2001 and subsequent missions were the subject of detailed reviews by independent teams during 1998. As a result, the design of the 2001 mission, and the architecture for the 2003 and follow-on missions, were revised to improve the likelihood of achieving the program's scientific goals within available resources.

The Mars 2001orbiter will perform global mapping of the surface elemental composition and high-resolution mapping of surface minerology, and will also provide high-spatial-resolution surface morphology. The lander will analyze and document surface soil composition, and will deploy a Sojourner-class rover. The mission will also collect data and demonstrate technologies critical to initiating the exploration of Mars by humans, thus meeting objectives set forth by the Human Exploration and Development of Space (HEDS) office.

The Mars 2003 mission will include Mars Express (built by ESA/ASI), which will perform global mapping and will provide communication capability that is expected to be compatible with Mars 2001. The Mars 2003 lander and the sampling rover will acquire samples that will be placed into orbit via a Mars Ascent Vehicle for future retrieval (Mars 2005 mission). The Mars 2003 mission will complete all the initial HEDS objectives for Mars Surveyor.

Funding for mission studies and for the technology activities that support the Mars Surveyor program are highly specific to this mission series; therefore, funding for these items is included in the Mars Surveyor budget.

Two new program elements are funded in the Mars Surveyor program beginning in FY 2000: Mars Network and Micromissions. The Mars Network will develop a communications capability to provide a substantial increase in bandwidth and connectivity from Mars to Earth. Although the specific missions and infrastructure needed to create this capability remain to be evaluated, one possible scenario is the development of one or more small relay satellites in orbit around Mars. These satellites could fulfill several user needs, such as increased connectivity for surface rover operations, high-sensitivity relay capability for small, energy-constrained microlanders, and increased data return rates for science and public outreach. The Mars Surveyor architecture review highlighted improved communications capability as the highest leverage augmentation that could be added to the program.

Mars Micromissions will provide a low-cost capability for delivering small payloads to Mars. For example, small "piggyback" spacecraft can be placed in a geosynchronous transfer orbit by an Ariane-5 expendable launch vehicle and then travel independently to Mars. Each of these competitively selected Principle Investigator class missions will deliver up to a 50-kilogram science payload to Mars to collect high-priority global scientific data. NASA, the French space agency CNES, and Arianespace will work together to establish micromissions as an important element of Mars exploration and infrastructure. The first micromission launch opportunity is planned for 2003. One of the leading concepts currently under review for this mission is a remotely piloted aircraft to provide enhanced mobility for Mars investigations.

SCHEDULE & OUTPUTS

1998 Mars Surveyor Orbiter and Lander

Start Orbiter environmental tests Plan: March 1998 Actual: March 1998	Confirm that the spacecraft can tolerate the launch and mission environments that it will face. Completed on schedule.
Start Lander environmental tests Plan: January 1998 Actual: January 1998	Confirm that the spacecraft can tolerate the launch and mission environments that it will face. Completed on schedule.
Ship Orbiter spacecraft Plan: August 1998 Actual: September 1998	Ship to the launch site. Slip had no impact.
Ship Lander Spacecraft Plan: October 1998 Actual: October 1998	Completed on schedule.
Launch Orbiter Plan: December 1998 Actual: December 1998	Launched on schedule.
Launch Lander Plan: January 1999 Actual: January 1999	Launched on schedule.

2001 Mars Surveyor Orbiter and Lander

Payload Confirmation Review Plan: 3rd Qtr 1998 Actual: 1st Qtr FY 1999	Confirm that the payload is sufficiently defined to move into full-scale development. Slip will not impact launch schedule.
Complete Phase B & start C/D Plan: 3rd Qtr FY 1998 Actual: 1st Qtr FY 1999	Complete definition study and initiate the development effort. Slip will not impact launch schedule.

Preliminary Design Review Plan: 3rd Qtr FY 1998 Actual: 1st Qtr FY 1999	Confirm that the science goals and objectives are achievable within Mission Design. Slip will not impact launch schedule.
Critical Design Review Plan: 2nd Qtr FY 1999 Current: 2nd Qtr FY 1999	Confirmation that the design is sufficient to move into full-scale development. On schedule.
Orbiter and Lander ATLO Start Plan: 1st Qtr FY 2000 Current: 1st Qtr FY 2000	Begin Assembly, Test and Launch Operations (ATLO) by integrating major components of the spacecraft into the spacecraft structure.
Orbiter & Lander Science Instr. Plan: 3rd Qtr FY 2000	Deliver Mars 2001 Orbiter and Lander science instruments that meet capability requirements. Pre-launch Gamma Ray Spectrometer (GRS) tests shall determine abundances in known calibration sources to 10% accuracy.
Ship Orbiter Plan: 1st Qtr FY 2001 Current: 2nd Otr FY 2001	Ship to VAFB launch site.
Ship Lander Plan: 2nd Qtr FY 2001 Current: 2nd Qtr FY 2001	Ship to KSC launch site.
Orbiter Launch Plan: March FY 2001 Current: March FY 2001	Launch on schedule
Lander Launch Plan: April FY 2001 Current: April FY 2001	Launch on schedule
Future Mars Surveyor Missions Plan: FY 2000	Assuming the Mars Surveyor Program architecture is confirmed: meet the milestones for the Mars 2003 instrument selection and initiate implementation of the lander mission. Deliver engineering models of the radio frequency subsystem and antennae for the radar sounder instrument to ESA (if ESA approves the Mars Express mission), and select contractors for major system elements of the Mars Surveyor 2005 mission.

ACCOMPLISHMENTS AND PLANS

The Mars Surveyor 98 mission, an orbiter and a lander, launched in December 1998 and in January 1999, respectively. For the Mars 2001 mission, Lockheed-Martin Aerospace, Denver, was selected as the spacecraft development contractor. The Mars 2001 Orbiter will include Gamma Ray Spectrometer (GRS), Thermal Emission Imaging System (THEMIS), and Mars Radiation Environment Experiment (MARIE). The Mars 2001 Lander will include a Pathfinder/Sojourner-type rover, as well as the Athena Precursor Experiment (APEX), Mars Descent Imager (MARDI), Mars Environmental Compatibility Assessment (MECA), Mars ISPP (In-situ Propellant Production) Precursor (MIP) and a copy of the MARIE experiment also found on the Orbiter. This instrument complement meets the science requirements of the Office of Space Science, the Office of Human Spaceflight, and the Office of Life and Microgravity Sciences and Applications. The spacecraft Preliminary Design Review took place in October 1998, with the Critical Design Review to take place in April 1999. The assembly and testing for the Lander and the Orbiter will begin in October 1999 and January 2000, respectively. The Orbiter and Lander are scheduled to launch in March and April of 2001, respectively.

A Mars Exploration Program Architecture Team was set up during the 3rd Qtr of FY 1998 to develop an architecture for the next decade (2001-2011) that will: achieve significant advances toward understanding the biological history of Mars; search for evidence of past and present life; and prepare the technological and scientific groundwork for Mars exploration in the following decade. The final recommendation is expected 2nd Qtr. 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

MISSION OPERATIONS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
HST operations	2,300	2,100	2,100
Other mission operations	136,400	104,200	83,200
Total	138,700	106,300	85,300

PROGRAM GOALS

The goal of the Mission Operations program is to maximize the scientific return from NASA's investment in spacecraft and other data collection sources. The Mission Operations effort is fundamental to achieving the goals of the Office of Space Science program because it funds the operations of the data collecting hardware that produces scientific discoveries. Funding supports satellite operations during the performance of the core missions, plus extended operations of selected spacecraft.

STRATEGY FOR ACHIEVING GOALS AND SCHEDULE & OUTPUTS

The Mission Operations program is working to dramatically reduce costs while preserving, to the greatest extent possible, science output. To do so, it will accept prudent risk, explore new conceptual approaches, streamline management and make other changes to enhance efficiency and effectiveness. The following is a comprehensive list of all Space Science spacecraft that are, or are expected to be, operational at any time between January 1999 and September 2000.

Advanced Composition Explorer (launched August 25, 1997; expected operations beyond FY 2000)
ACE is measuring the composition of the particles streaming from the Sun, as well as high-energy galactic cosmic rays.

> FY 2000 performance: ACE will measure the composition and energy spectra of heavy nuclei in at least eight solar energetic particle events; maintain real-time solar wind data transmissions at least 90% of the time; measure the isotopic composition of a majority of the "primary" galactic cosmic ray elements from carbon to zinc; and provide browse parameters within three days for 90% of the year.

Advanced Spacecraft for Cosmology Astrophysics (launched February 20, 1993; expected operations beyond FY 2000)
ASCA is Japan's fourth cosmic X-ray astronomy mission, and the second for which the United States provided part of the scientific payload.

Advanced X-ray Astrophysics Facility (launch no earlier than May, 1999; expected operations through ~ FY 2009)
The AXAF mission operations budget includes support for the pre-launch development of the AXAF ground system. Post-launch AXAF operations will be conducted from a control center at the AXAF Science Center (ASC) in Boston, developed by the Massachusetts Institute of Technology.

FY 2000 performance: The AXAF instruments will meet nominal performance expectations, and science data will be taken with 70% efficiency with at least 90% of science data recovered on the ground.

Astro-E (launch scheduled February 2000; expected operations beyond FY 2000)
Astro-E will permit an unprecedented sensitivity study of a wide range of astrophysical sources, answer many outstanding questions in astrophysics, and likely pose many new ones

FY 2000 performance: If launched, activate the X-ray Spectrometer (XRS) and X-ray Imaging Spectrometer (XIS) instruments on the Japanese Astro-E spacecraft after launch and collect at least 90% of the XRS and XIS data.

Cassini (launched October 15, 1997; expected operations through ~ 2008)
Cassini will conduct a detailed exploration of the Saturnian system including: 1) the study of Saturn's atmosphere, rings and magnetosphere; 2) remote and in-situ study of Saturn's largest moon, Titan; 3) the study of Saturn's other icy moons; and 4) a Jupiter flyby to expand our knowledge of the Jovian System. Cassini will arrive at Saturn in 2004. Proper trajectory is ensured through tracking and targeting maneuvers, and the health of science instruments is maintained by periodic checkouts.

FY 2000 performance: Continue Cassini operations during the quiescent cruise phase without major anomalies, conduct planning for the Jupiter gravity-assist flyby, and explore early science data collection opportunities. The following in-flight activities will be completed: Instrument Checkout#2; uplink Articulation & Attitude Control Subsystem (AACS) software update with Reaction Wheel Authority capability; Command & Data Subsystem Version 8; and Saturn Tour designs for selection by the Program Science Group.

Compton Gamma-Ray Observatory (CGRO) (launched April 5, 1991; expected operations beyond FY 2000)
CGRO is the second of NASA's Great Observatories. It has a diverse scientific agenda, including studies of very energetic celestial phenomena: solar flares, cosmic gamma-ray bursts, pulsars, nova and supernova explosions, accreting black holes of stellar dimensions, quasar emission, and interactions of cosmic rays with the interstellar medium.

FY 2000 performance: Continue to operate those instruments not dependent on expended consumables (Oriented Scintillation Spectrometer Experiment, OSSE; Burst and Transient Source Experiment, BATSE; and Imaging Compton Telescope, COMPTEL) at an average efficiency of at least 60%.

Deep Space 1 (launched October 24, 1998; expected operations beyond FY 2000)
During its two-year primary mission, DS1 will test 12 revolutionary technologies destined for future missions. The new technologies on board the DS1 spacecraft will be proven in arduous spaceflight conditions, so that 21st-century missions can use them with confidence. The DS1 spacecraft will fly by and gather data about an asteroid, and then if the mission is extended by a year, a comet. Heralding future solar system missions, DS1 is the first to use high-performance, solar electric ion propulsion.

Deep Space 2 (launched January 3, 1999 ; expected operations through December 1999)
In December 1999, two basketball-sized aeroshells will crash onto the Martian surface. Each aeroshell will shatter on impact, releasing a miniature two-piece science probe that will punch into the soil to a depth of up to 1 meter. The microprobes' primary science goal is to determine if water ice is present in the Martian subsurface - an important clue in the puzzle of whether life exists, or ever existed, on Mars. The tiny science stations will also measure temperature and monitor local Martian weather.

Extreme Ultraviolet Explorer (launched June 7, 1992; expected operations through September 1999)
EUVE is studying the sky at wavelengths once believed to be completely absorbed by the thin gas between the stars.

Fast Auroral Snapshot (FAST) (launched August 21, 1996; expected operations beyond FY 2000)
FAST is a low-altitude polar orbit satellite designed to measure the electric fields and rapid particle accelerations that occur along magnetic field lines above auroras. Extremely high data rates (burst modes) are required to detect the presence and characteristics of the fundamental effects taking place.

> FY 2000 performance: FAST shall return simultaneous data from high-latitude, low-altitude magnetosphere locations in the Sun-Earth connected system through solar maximum at the required resolution and accuracy with at least 85% efficiency. Data are used in conjunction with data from ISTP and TIMED.

Far Ultraviolet Spectroscopic Explorer (FUSE) (launch scheduled May 1999; expected operations beyond FY 2000)
FUSE will conduct high-resolution spectroscopy in the far ultraviolet region.

> FY 2000 performance: The three-year FUSE mission will complete at least one third of the observations needed for its minimum science program with 6 of the 8 instrument performance parameters being met.

Galileo (launched October 18, 1989; expected operations through December 1999)
Galileo is executing a series of close flybys of Jupiter and its moons, studying surface properties, gravity fields and magnetic fields, and characterizing the magnetospheric environment of Jupiter and the circulation of its Great Red Spot. In December 1997, the program began the Galileo Europa Mission (GEM), a detailed study of Jupiter's ice-covered moon running through 1999.

> FY 2000 performance: Recover at least 90% of playback data from at least 1 Galileo fly-by of Io.

High Energy Solar Spectroscopic Imager (launch scheduled July 2000, expected operations beyond FY 2000)
HESSI will observe the Sun to study particle acceleration and energy release in solar flares.

FY 2000 performance: Assuming launch and normal checkout, HESSI operations will return data to achieve at least the primary science objectives, with at least 80% coverage of the time allowed by orbit.

Highly Advanced Laboratory for Communications and Astronomy (launched February 12, 1997; expected operations beyond FY 2000)
HALCA is led by Japan's Institute of Space and Astronautical Science. The project allows imaging of astronomical radio sources with a signficantly improved resolution over ground-only observations. The JPL VLBI project provides support for the U.S. tracking stations associated with HALCA, coordinates U.S. science efforts together with the National Radio Observatory (NRAO), and ensures the delivery of high-quality science data to successful U.S. proposers.

Hubble Space Telescope (launched April 25, 1990; expected operations through ~2010)
HST science operations are carried out through an independent HST Science Institute, which operates under a long-term contract with NASA. Satellite operations, including telemetry, flight operations and initial science data transcription, are performed on-site at Goddard Space Flight Center under separate contract. While NASA retains operational responsibility for the observatory, the Science Institute plans, manages, and schedules the scientific operations.

FY 2000 performance: Maintain an average HST on-target pointing efficiency of 35% during FY00 operations before they are interrupted for the third servicing mission, presently scheduled for May 2000.

Imager for Magnetopause-to-Aurora Global Exploration (launch scheduled February 2000, expected operations beyond FY 2000)
IMAGE will study the global response of the Earth's magnetosphere to the changes in the solar wind.

FY 2000 performance: If launched, IMAGE will acquire critical measurements at minute time scales, returning 85% real-time coverage of the Earth's magnetospheric changes.

International Solar-Terrestrial Physics (ISTP)
Geotail (launched July 24, 1992; expected operations beyond FY 2000)
Wind (launched November 1, 1994; expected operations beyond FY 2000)
Polar (launched February 24, 1996; expected operations beyond FY 2000)
Solar and Heliospheric Observatory (SOHO) (launched December 2, 1995; expected operations beyond FY 2000)
Wind, Polar, SOHO, and Geotail are the core spacecraft of the ISTP program. Wind measures the energy, mass, and momentum that the solar wind delivers to the Earth's magnetosphere. Wind also carries a gamma ray instrument, the first Russian instrument ever to be flown on a U.S. spacecraft. Polar provides dramatic images of the aurora and complementary measurements to provide a direct measure of the energy and mass deposited from the solar wind into the polar ionosphere and upper atmosphere. SOHO

studies the solar interior by measuring the seismic activity on the surface; SOHO also investigates the hot outer atmosphere of the Sun that generates the variable solar wind and UV and X-ray emissions affecting the Earth's upper atmosphere, the geospace environment, and the heliosphere. Geotail is a Japan-U.S. spacecraft that explored the deep geomagnetic tail in its first two years of flight and now is exploring the near-tail region on the night side and the magnetopause on the day side of the Earth.

FY 2000 performance: Collect 85% of data acquired from the ISTP spacecraft; successfully execute the WIND trajectory plan.

Interplanetary Monitoring Platform-8 (launched October 26, 1973; expected operations beyond FY 2000)
IMP-8 performs near-continuous studies of the interplanetary environment for orbital periods comparable to several rotations of the active solar regions.

FY 2000 performance: Collect and process data from the Interplanetary Monitoring Platform, making data from at least 6 instruments available within 15 months, and the magnetic field and plasma data available within 2 months

Lunar Prospector (launched January 6, 1998; expected operations through August 1999)
Beginning in November 1998, the orbit of the spacecraft was lowered to about 30 miles above the Moon's surface in order to maximize its scientific return during the final months of operation.

Mars Climate Orbiter (launched December 11, 1998; expected operations beyond FY 2000)
Upon arrival at Mars in September 1999, MCO will use a series of aerobraking maneuvers to achieve a stable orbit, and then use atmospheric instruments and cameras to provide detailed information about the surface and climate of Mars.

FY 2000 performance: In May 2000 MCO will aerobrake from its initial insertion orbit into a near-polar, sun-synchronous, approximately 400km circular orbit, and will initiate mapping operations.

Mars Global Surveyor (launched November 7, 1996; expected operations beyond FY 2000)
MGS will return an unprecedented amount of data regarding Mars' surface features, atmosphere, and magnetic properties. The spacecraft reached Mars in September 1997 and has begun the aerobraking maneuvers to achieve its desired mapping orbit in March 1999, about one year later than planned due to unanticipated deflections in one of the solar array panels. No loss of science is anticipated.

FY 2000 performance: Acquire 70% of science data available, conduct at least two 5-day atmospheric mapping campaigns, and relay to Earth at least 70% of data transmitted at adequate signal levels by the DS2 Mars microprobes.

Mars Polar Lander (launched January 3, 1999; expected operations through February 2000)
In December 1999 MPL will soft land, under propulsive power, near the edges of the South Polar ice cap on Mars. Since it lands in the Martian summertime, only remnants of the cap may be observed. The lander is equipped with cameras, a robotic arm and instruments to measure the Martian soil composition.

FY 2000 performance: In December 1999 MPL will successfully land on Mars and operate its science instruments for the 80-day primary mission with at least 75% of planned science data returned.

Near Earth Asteroid Rendezvous (launched February 17, 1996; expected operations beyond FY 2000)
NEAR flew by Earth for its final gravity assist in January 1998, and will arrive at its primary target (the asteroid 433 Eros) in February 2000. Originally scheduled for Eros rendezvous in February 1999, the start of prime science operations has been delayed by a premature cut-off during the first orbit insertion engine firing in December 1998.

FY 2000 performance: NEAR will successfully orbit 433 Eros and meet primary scientific objectives while not exceeding projected mission cost.

Nozomi (launched July 3, 1998; expected operations beyond FY 2000)
NASA provided a Neutral Mass Spectrometer to the Japanese Institute of Space and Astronautical Science (ISAS), for launch to Mars aboard the Nozomi spacecraft. The project objective is to study the structure and dynamics of the atmosphere and ionosphere of Mars, including any interactions with the solar wind.

Rossi X-ray Timing Explorer (launched December 30, 1995; expected operations beyond FY 2000)
RXTE uses three instruments to conduct timing studies of astronomical X-ray sources.

FY 2000 performance: Operate at least three of the five instruments at an efficiency of 45% with 95% data recovery. All Sky Monitor data will be posted on the web within 7 days, and Proportional Counter Array and High-Energy X-ray Timing Experiment data released within 60 days.

Solar Anomalous and Magnetospheric Particle Explorer (launched July 3, 1992; expected operations beyond FY 2000)
SAMPEX is measuring the composition of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays.

FY 2000 performance: Obtain at least 60% data coverage from at least three of SAMPEX's four instruments.

Stardust (launch scheduled for February 1999; expected sample return to Earth in 2006)
Stardust will perform activities in support of the five-year cruise to rendezvous with Comet Wild-2.

FY 2000 performance: Continue cruise operations without major anomalies and perform interstellar dust collection for at least 36 days.

Student Nitric Oxide Experiment (launched February 25, 1998; operations expected through April 1999)
SNOE is a small scientific satellite investigating the effects of energy from the sun and from the magnetosphere on the density of nitric oxide in the Earth's upper atmosphere. SNOE was designed and built, and is being operated, entirely at the University of Colorado at Boulder.

Submillimeter Wave Astronomy Satellite (launched December 5, 1998; expected operations through January 2000)
SWAS studies the chemical composition, energy balance and structure of interstellar clouds and the processes that lead to the formation of stars and planets.

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (launch scheduled May 2000; expected operations beyond FY 2000)
TIMED will explore the Earth's Mesosphere and Lower Thermosphere (60-180 kilometers), the least explored and understood region of our atmosphere.

> FY 2000 performance: If successfully launched, TIMED will acquire global data in the Mesosphere Lower Thermosphere/Ionosphere region globally (all latitudes) for at least 90 days at the required spatial resolution, coverage, accuracy and for all local solar times.

Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (launch scheduled April 1999; operations expected through April 2000)
TERRIERS will study a number of ionospheric and thermospheric phenomena, and will test the utility of long term solar EUV (extreme ultraviolet) irradiance measurements. TERRIERS is a Boston University student satellite project selected for the Student Explorer Demonstration Initiative program (STEDI).

Transition Region and Coronal Explorer (launched April 1, 1998; expected operations through April 2000)
TRACE observes the effects of the emergence of magnetic flux from deep inside the Sun to the outer corona with high resolution.

> FY 2000 performance: Collect pixel-limited images in all TRACE wavelength bands, operating 24-hour schedules for sustained periods over 8 months. TRACE will operate with Yohkoh, HESSI and ground based observatories as a coordinated system to obtain both images and spectral data on the quiet Sun, sunspots, and active solar regions.

Ulysses (launched October 6, 1990; expected operations beyond FY 2000)
Ulysses is currently studying the heliospheric environment out to the orbit of Jupiter by measuring the interplanetary medium and solar wind as a function of heliographic latitude.

> FY 2000 performance: Capture at least 90% of available science data, the only data observed from out-of-the-ecliptic plane.

Voyager Interstellar Mission (Voyager 1 launched September 5, 1977; Voyager 2 launched August 20, 1977; expected operations beyond FY 2000)
Voyager 1 and 2 are continuing to probe the outer heliosphere and look for the heliospheric boundary with interstellar space as they travel beyond the planets.

FY 2000 performance: Average 12 hours of Voyager Interstellar Mission data capture per day per spacecraft to characterize the heliosphere and the heliospheric processes at work in the outer solar system as well as the transition from the solar system *to* interstellar space

Yohkoh (launched August 31. 1991: expected operations beyond FY 2000)

Yohkoh. a cooperative program with the Japanese, gathers X-ray and spectroscopic data on solar flares and the corona.

FY 2000 performance: Acquire calibrated observational data from the Japanese Yohkoh high-energy solar physics mission (including the U.S. -provided Soft X-ray Telescope (SXT)) for a t least 75% of the time permitted by tracking coverage.

ACCOMPLISHMENTS AND PLANS

Space Science continues to make progress in lowering mission operations costs while preserving the science return from operating missions. The program is utilizing the savings, gnd seeking additional cost reductions, in order to sustain operations of ongoing missions as long as is merited by the science return. The science community both inside and outside of NASA regularly reviews the mission operations program to ensure that only the missions with the highest science return are funded. In addition. we are launching smaller spacecraft, and engaging in more international collaborations. As a result, NASA expects *to* be able to support an increasing number of operational spacecraft through FY 2000 despite a smaller MO budget. In total, we will have about 34 operational Space Science spacecraft at the end of FY 2000. compared to 18 at the beginning of FY 1995. As of the end of January 1999. we have 27 operational missions (29 spacecraft). Missions expected to begin operations before the end of FY 2000 include Stardust (2/99). WIRE (2/99). TERRIERS (4/99). AXAF (4/99). FUSE (5/99). HETE-II (11/99). XMM (1/00). IMAGE (2/00). Astro-E (2/00). TIMED (5/00). Cluster-I1 (6/00). and HESSI (7/00).

BASIS OF FY 2000 FUNDING REQUIREMENT

SUPPORTING RESEARCH AND TECHNOLOGY

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Supporting Research and Technology	894,000	945,200	1,152,100
Technology Program	469,000	484,900	642,600
Core Program	189,900	207,000	259,000
Space Science Technology	63,600	56,700	96,900
Cross-Enterprise Technology	126,300	150,300	162,100
Focused Programs	200,000	251,500	367,500
[Construction of Facilities	--	[2,500]	[2,500]
Flight Validation (New Millennium Program	79,100	26,400	16,100
Research Program	386,600	417,200	472,000
Research and Analysis	137,900	194,200	182,200
Data Analysis	248,700	223,000	289,800
Suborbital*	38,400	43,100	37,500
ELV (Non-add)	[32,800]	[9,500]	[12,500]

* The Suborbital program, while included in the SR&T budget, is discussed in a separate section, next under.

PROGRAM GOALS

OVERALL SUPPORTING RESEARCH AND TECHNOLOGY

The Space Science Enterprise's Supporting Research and Technology program is comprised of three major components: the Technology program, the Space Science Research program (consisting of Research and Analysis and Data Analysis) and the Suborbital program. These three elements focus on the activities that occur both before and after space flight mission development and operations. The Technology and Research programs are discussed in this section: Suborbital activities are discussed in the next section. The proper levels of investment in technology, research and suborbital programs are essential to obtaining the high-value scientific results that will enable the Space Science Enterprise to fulfill its mission: to solve the mysteries of the universe including its origins and destiny, explore the solar system, discover planets around other stars, and search for life beyond Earth.

TECHNOLOGY PROGRAM

The goals of the Technology Program are to (1) lower mission life-cycle costs; (2) develop innovative technologies; (3) develop and nurture an effective science-technology partnership; (4) stimulate cooperation among industry, academia, and government; and (5) identify and fund the development of important cross-Enterprise technologies.

SPACE SCIENCE RESEARCH PROGRAM

The goals of the Space Science Research and Analysis Program are: (1) to enhance the value of current space missions by carrying out supporting ground-based observations and laboratory experiments; (2) to conduct the basic research necessary to understand observed phenomena, and develop theories to explain observed phenomena and predict new ones; and, (3) to continue the analysis and evaluation of data from laboratories, airborne observatories, balloons, rocket experiments and spacecraft data archives. In addition to supporting basic and experimental astrophysics, space physics, and solar system exploration research for future flight missions, the program also develops and promotes scientific and technological expertise in the U.S. scientific community.

The goal of the Space Science Data Analysis program is to maximize the scientific return from our space missions, within available funding. The Data Analysis program is the source of the enormous scientific return generated from our investments in space hardware. Besides scientific advancements, the Data Analysis program also contributes to public education and understanding through media attention and our own education and outreach activities.

STRATEGY FOR ACHIEVING GOALS

TECHNOLOGY

The Space Science Enterprise's Technology Program consists of three major elements: core program, focused programs, and flight validation. These elements are designed to develop technologies from the conceptual stage to the point where they are ready to be incorporated in the full-scale development of science mission spacecraft.

Core Programs are comprised of two major components: Space Science Technology and Cross-Enterprise Technology.

Space Science Technology supports the development of enabling technologies for the next generation of high-performance Space Science missions. Retiring technological risk early in the mission design cycle, while emphasizing innovation to reach previously unattainable goals in mass reduction and performance, are key to the success of many of the missions planned for the next century. The Space Science Technology program includes Explorer Program Technology, Information Systems, High Performance Computing and Communications (HPCC), science instrument development, planetary flight support, and other OSS core technology. These elements are described below:

- Explorer Program Technology develops leading-edge technologies to enable partnerships in relatively small technology projects with industry, academia, NASA Field Centers, and other government agencies. These technologies must show application across multiple systems or missions, with an emphasis on meeting Explorer Program technology needs for improved spacecraft and instrument systems, and must also lead to lower mission costs.

- Information Systems provides technology for multidisciplinary science support in the areas of data management and archiving, networking, scientific computing, visualization, and applied information systems research and technology.

- The NASA HPCC Program will accelerate the development, application, and transfer of high-performance computing technologies to meet the science and engineering needs of the U.S. science community and the U.S. aeronautics community. Within this program the Space Science Enterprise funds the Remote Exploration and Experimentation (REE) component, which will develop low-power, fault-tolerant, high-performance, scaleable computing technology for a new generation of microspacecraft.

- Science instrument development funds initial technology work on new types of detectors and other scientific instruments. Many of these new instrument concepts are tested and flown aboard sounding rockets or balloons, and may later be adapted for flight aboard future free-flying spacecraft.

- The Planetary Flight Support (PFS) program provides ground system hardware, software, and mission support for all deep space missions. Planetary flight support activities are associated with the design and development of multi-mission ground operation systems for deep space and high-Earth-orbiting spacecraft. PFS also supports the development of generic multi-mission ground system upgrades such as the Advanced Multi-mission Operations System (AMMOS). This new capability is designed to significantly improve our ability to monitor spacecraft systems, resulting in reduced workforce levels and increased operations efficiencies for Cassini and future planetary missions. New missions in the Discovery and Mars Surveyor programs will work closely with the Planetary Flight Support Office to design ground systems developed at minimum cost, in reduced time, with greater capabilities, and able to operate at reduced overall mission operations costs.

- Other Space Science Core Technology provides funding to those technologies that are applicable to multiple focused programs (described below). Technologies eventually move from this category into a focused program if they are determined to be feasible and applicable to specific Space Science needs.

Two elements previously included in this category: Advanced Radioisotope Power System (ARPS) and the Center for Integrated Space Microsystems (CISM), have been moved to the Advanced Deep Space Systems focused program, since these technologies support the missions included under Advanced Deep Space Systems.

The Cross-Enterprise Technology program supports the cross-cutting technology requirements for all NASA Space Enterprises. The technologies are generally multi-mission in nature and this work tends to focus on the earlier stages of the technology life-cycle. The technologies developed under the Cross-Enterprise program form the foundation for most new spacecraft, robotics, and information technologies eventually flown on NASA missions.

A new feature of the Cross-Enterprise Technology program is the use of NASA Research Announcements (NRA) to broadly announce and compete an increasingly larger portion of the program. This will open up opportunities to a wider community of technology developers and will ensure the excellence of the program through peer-reviewed competition. The implementation of the NRA process in Cross-Enterprise Technology will begin in FY 99.

A second change implemented in FY 99 is the change in Cross-Enterprise Technology program structure. The new program structure is based on integrated, systems level "thrust areas", which are more clearly aligned with multi-Enterprise requirements and reflect the way the technology development work is managed. The thrust areas are as follows:

- Advanced Power and On-Board Propulsion: Subsystems and components that handle power generation, energy storage, and in-space propulsion to enable crewed and robotic spacecraft to travel faster and deeper into space, with longer mission duration.
- Sensors and Instrument Components: Breakthrough technologies for a wide range of remote sensing and observational capabilities for use in Space Science and Earth Science applications.
- Distributed Spacecraft: Precision formation-flying technologies, spacecraft constellations, and fleet control technologies.
- High Rate Data Delivery: Technologies to more efficiently collect, transmit, receive, store and access data from operational missions.
- Micro/Nano Spacecraft: Technologies to enable smaller, lower mass spacecraft with greater functionality. This area will also integrate developments from other thrust areas, such as miniature power, propulsion, instruments, and other components into functioning miniature spacecraft.
- Surface Systems: Technologies for spacecraft to operate and explore on the surface, below the surface, or in the atmospheres of planetary and other celestial bodies.
- Thinking Space Systems: Development of thinking, inquisitive, self-commanding systems that can recognize objects or phenomena of scientific interest and then conduct observations accordingly.
- Ultralight Structures and Space Observatories: Technologies enabling the deployment of large, lightweight space structures. These include precision deployment capabilities, membrane and inflatable structures, and high performance materials.
- Next Generation Infrastructure: Development of technologies to vastly improve the ability to conceive, design, test, and operate future space systems.

In FY 2000, additional funding for the Cross-Enterprise Technology program budget is provided to support three new initiatives: Self-sustaining Robotic Networks, Gossamer Spacecraft, and Next Decade Planning. Self-sustaining Robotic Networks ($24 million in FY 2000) will build on the success of Mars Pathfinder. This initiative's goal is to extend ongoing advances in spacecraft automation and minaturization to the critical set of technologies necessary to enable self-tasking, self-repairing, evolvable networks of small, highly mobile rovers for "virtual presence" planetary science and exploration in challenging environments. This funding will be placed in those thrust areas developing the relevant technologies, e.g., thinking space systems, surface systems, etc. Part of this funding is provided under the Administration's Information Technology (IT) initiative.

The Gossamer Spacecraft initiative will provide additional funding ($6 million in FY 2000) to the ultralight structures and space observatories thrust area to develop and demonstrate the deployment, control, and utility of thin-film deployable structures. Technologies developed in this area could support several future applications: solar sail propulsion, large aperture astronomical observatories, large aperture remote sensing, large-scale power collection and transmission in space, and interstellar precursor missions.

Next decade planning ($5 million in FY 00) will support improved cross-agency planning with the objective of improving technology selection through the ongoing development and refinement of a robust set of potential civil space programs that could be undertaken in the next decade.

Focused Programs are dedicated to high-priority technologies needed for specific science missions. An aggressive technology development approach is used that allows all major technological hurdles to be cleared prior to a science mission's development phase. Technology activities can encompass developments from basic research all the way to infusion into science missions. Focused Programs also includes mission studies -- the first phase of the flight program development process. Scientists work collaboratively with technologists and mission designers to develop the most effective alignment of technology development programs with future missions. This collaboration enables intelligent technology investment decisions through detailed analysis of the trade-offs between design considerations and cost. In order to ensure that the decisions resulting from mission studies are realistic and can be implemented, the studies will employ new techniques for integrated design and rapid prototyping.

The FY 2000 budget estimate includes four categories of activities under focused programs. These categories correspond to the four scientific themes of the Space Science Enterprise: Astronomical Search for Origins, Advanced Deep Space Systems Development (Solar System Exploration), Sun-Earth Connections, and Structure and Evolution of the Universe. These elements are described below:

- Astronomical Search for Origins Technology develops critical technologies for studies of the early universe and of extra-solar planetary systems. Included are large lightweight deployable structures, precision metrology, vibration isolation and structural quieting systems, optical delay lines and large lightweight optics. Missions supported in this area include the Space Interferometry Mission (SIM), Next Generation Space Telescope (NGST), and Terrestrial Planet Finder (TPF), as well as the provision of interferometry capability to the ground-based Keck telescopes. This line also funds construction of the Optical Interferometry Development Laboratory at the Jet Propulsion Laboratory.

- Advanced Deep Space Systems Technology provides for the development, integration, and testing of revolutionary technologies for solar system exploration. Emphasis will be on micro-avionics, autonomy, computing technologies, and advanced power systems. Funding for CISM and ARPS, previously budgeted in Core Technology, is now included in this line. Funding in this area supports a Europa orbiter mission with a launch date in 2003, and a potential Pluto/Kuiper Express mission in 2004. Technology developed in this area also supports Solar Probe (a Sun-Earth Connections mission), which shares a significant amount of common technology with Europa and Pluto/Kuiper Express.

- Sun-Earth Connections Technology develops the technologies necessary for missions focused on observing the Sun and the effects of solar phenomena on the space environment and on the Earth. Technology funded in this area supports missions now under study such as STEREO, Solar-B, Solar Probe, as well as future SEC missions.

- Structure and Evolution of the Universe Technology provides for the development of technologies to study the large-scale structure of the universe, including the Milky Way and objects of extreme physical conditions. SEU missions are aimed at explaining the cycles of matter and energy in the evolving universe, examining the ultimate limits of gravity and energy in the universe and forecasting our cosmic destiny. Technology funded in this area supports missions now under study, such as FIRST and GLAST, as well as future SEU missions, particularly Constellation-X.

Flight Validation Program (also referred to as the New Millennium Program) provides a path to flight-validate key emerging technologies to enable exciting science missions. Breakthrough and enabling technologies are incorporated into spacecraft to provide a relevant flight testbed environment to validate the new technologies. Partnerships with industry, universities, and other government agencies are pursued, where feasible, to maximize both the return on investment in technology development and rapid infusion. Through the New Millennium Program (NMP), high-value technologies are made available for use in the Space Science program without imposing undue cost and risk on individual science missions. The New Millennium Program is funded by both the Space Science Enterprise and the Earth Science Enterprise.

In keeping with the focus of the New Millennium Program on providing flight validation of broadly applicable technologies, the NMP Deep Space-3 demonstrator, which will validate interferometry technologies to benefit future interferometry missions such as Terrestrial Planet Finder, has been moved to the Astronomical Search for Origins focused program. Similarly, the Deep Space-4 mission (Champollion/Comet Lander) has been moved to the Deep Space Systems focused program, since this mission to land on the surface of a comet benefits the objectives of the Solar System Exploration scientific theme. Moreover, the designation for these projects, along with all future New Millennium-type projects, has changed from Deep Space (DS) to Space Technology (ST), to reflect the fact that not all of the Space Science-funded demonstrators go to deep space. Thus, from this point on, DS-3 will be known as ST-3, and DS-4 as ST-4.

RESEARCH

The Space Science Research and Analysis Program carries out its goals and objectives by providing grants to universities, nonprofit and industrial research institutions, as well as by funding scientists at NASA Field Centers and other government agencies. Approximately 1,500 grants are awarded each year after a rigorous peer review process; only about one out of four proposals is accepted for funding. This scientific research is the foundation of the Space Science Enterprise. Key research activities include the analysis and interpretation of results from current and past missions; synthesis of these analyses with related airborne, suborbital, and ground-based observations; and the development of theory, which yields the scientific questions to motivate subsequent missions. The publication and dissemination of the results of new missions to scientists and the world is another key element of the Research and Analysis Program strategy, since it both inspires and enables cutting-edge research into the fundamental questions that form the core of the mission of the Space Science Enterprise.

The Space Science Data Analysis program supports scientific teams using data from our spacecraft. Depending on the mission, scientists supported may include Principal Investigators who have built hardware and been guaranteed participation, Guest Observers who have successfully competed for observing time, and researchers using archived data from current or past missions. Data analysis funding also supports a number of critical "Science Center" functions that are necessary to the operation of the spacecraft but do not involve the actual commanding of the spacecraft. For instance, the planning and scheduling of spacecraft observations, the distribution of data to investigators, and data archiving services are all supported under Data Analysis.

SCHEDULE & OUTPUTS

Technology Program

Space Science Core Technology

REE - FY 2000 Goals	The Remote Exploration and Experimentation (REE) element of the High Performance Computer and Communications (HPCC) program will demonstrate software-implemented fault tolerance for science applications. The target is to demonstrate applications on a first generation embedded computing testbed, with sustained performance degraded by no more than 25%, at fault rates characteristic of deep space and low Earth orbit.
First Generation computing testbed Plan: 2nd Qtr FY 1999	Install first generation scaleable embedded computing testbed operating at 30-200 MOPS/watt.
Demonstrate scaleable computer for spaceborne applications Plan: 3rd Qtr. FY 1999	Demonstrate scaleable spaceborne applications on first-generation embedded computing testbed.

Info System R&T - FY 2000 Goals	Information Systems R&T will demonstrate search, discovery, and fusion of multiple data products at a major science meeting; accomplish and document the infusion of 5 information systems R&T efforts into flight projects for the broad research community; and space science data services shall be acknowledged as enabling for 2 interdisciplinary collaborations.

Cross-Enterprise Technology

Develop wide-band low-power electronically-tuned local oscillator sources up to 1.3 THz Plan: 3rd Qtr. FY 98 Revised: 4th Qtr. FY 99	This technology supports planned astronomy missions such as the Far Infrared Space Telescope (FIRST) mission to spectroscopically measure the chemical make-up of interstellar gases and nebulae. Plan has been revised to allow for incorporation of a new approach, using amplifiers which promise better performance (wider bandwith and lower power) to be incorporated into the local oscillator sources.
Develop a small advanced monopropellant rocket Plan: 4th Qtr. FY 98 Actual: 4th Qtr. FY 98	Fabricate and test flight-type nontoxic monopropellant system developed in FY 97. Completed on schedule.
Demonstrate 25% efficient Production-quality solar cells Plan: 4th Qtr. FY 98 Actual: 4th Qtr. FY 98	Pilot production of these efficient, new multi-band gap, large format solar cells will be done in FY 98. Completed on schedule.
NRA Release Plan: 2nd Qtr. FY 99	Release NASA Research Announcement (NRA) for Cross-Enterprise technology development.
Task selections Plan:4th Qtr. FY 99	Select tasks following competitive review of proposals submitted in the above NRA.
Conduct on-orbit Ranger telerobotic flight experiment Plan: 4th Qtr. FY 99 Current: Under review	This experiment will demonstrate multiple on-orbit robotic servicing capabilities relevant to science payload servicing and Space Station assembly and maintenance. The experiment has been temporarily removed from the manifest to accommodate other priorities. A late-FY 00 launch date is currently being evaluated.
Increase number of tasks at TRL 3 and below Plan: End of FY 2000	The number of tasks funded at technology readiness level (TRL) 3 (proof of concept) is a measure of the portion of the Cross-Enterprise program focused on early development, where a premium is placed on identification and "seed" support of leap-ahead technology developments. The goal is to increase TRL 3 tasks in FY 2000 by 100 vs. the FY 1999 level of slightly more than 200.

100% of tasks subjected to full and open competition and/or external non-advocate review Plan: End of FY 2000	This goal will maintain the emphasis of maximizing competition in the cross-enterprise technology program.

Focused Programs

Origins

ST 3 Project Start Plan: October 1997 Actual: February 1998	Begin Phase A.
KECK Interferometer Optics Telescope PDR Plan: August 1998 Actual: August 1998	Conduct Preliminary Design Review (PDR) for the build of 2-4 two-meter outrigger telescopes. Following contractor selection in June 1998, the PDR was completed on schedule.
ST 3 System Arch. Review Plan: August 1999	System Architecture & Requirements Review
Space Interferometry Mission (SIM) Plan: 2nd-4th Qtr. FY 1999	Continue Phase B activities and conduct the preliminary non-advocate review of the high precision astrometry and synthetic aperture imaging technologies for space-based interferometers. Key features include optical collectors on a 10-meter baseline and 10-milli-arcsecond synthesized imaging.
SIM Testbed Demo Plan: May 2000	The (SIM) System Testbed (STB) will demonstrate that RMS optical path difference can be controlled at 1.5 nanometers, operating in emulated on-orbit mode.
Keck fringe detection - FY 2000 Goal	Interferometric capabilities will be tested by detecting and tracking fringes with two test siderostats at 2 and 10 micron wavelengths
NGST – FY 2000 Goal	Complete the Next Generation Space Telescope (NGST) Developmental Cryogenic Active Telescope Testbed (DCATT) phase 1, measure ambient operation with off-the-shelf components, and make final preparations for phase 2, the measurement of cold telescope operation with selected "flight-like" component upgrades. These technologies are needed to mitigate risk in phasing and controlling segmented optics for the mission.

Deep Space

ST 4 Project Start Plan: October 1997 Actual: October 1997	Begin Phase A.
CISM Curriculum Plan: 4^{th} Qtr. FY 1998 Current: 4^{th} Qtr. FY 1999	Develop university curriculum for two CISM technology thrust efforts: Systems on a Chip, and Revolutionary Computing Technologies. Curriculum for Systems on a Chip completed July 1998. Curriculum for Revolutionary Comp. Tech. is expected to be completed 4^{th} Qtr. FY 1999.
X-2000 Testbed design Plan: 4^{th} Qtr FY 1999	First delivery of an integrated and tested spacecraft avionics testbed design.
Solar System Exploration (non-Mars) First mission C/D start FY 2000 Goal	Successfully complete a preliminary design for either the Europa Orbiter or Pluto-Kuiper Express mission, whichever is planned for earlier launch, that is shown to be capable of achieving the Category 1A science objectives with adequate cost, mass, power and other engineering margins.
ARPS Plan: March 2000	Fabricate and test 15 prototype AMTEC cells and Complete the final design of Alkali Metal Thermo-Electric Converter (AMTEC) cells
ARPS Plan: April 2000	Complete the final design for a 75-watt ARPS
X-2000 EM-1 Plan: April 2000	Deliver the first engineering model (EM-1) to the X-2000 project.
CISM Plan: 3^{rd} Qtr FY 2000	Deliver first engineering model of an integrated avionics system.
Europa Orbiter Avionics Engineering Model I&T Plan: July 2000	Begin integration and test of the Avionics Engineering Model in 7/00.
ST 4 Critical Design Review Plan: September 2000	Complete the system CDR for DS4/Champollion, including successful completion of the avionics subsystem CDR and the mechanical subsystem CDR.
ARPS Plan: September 2000	Begin the prototype AMTEC 4-cell lifetime test and begin qualification unit fabrication

SEC

Complete phase B and transition to detailed design for Solar-B instruments Plan: 4th Qtr. FY 1999	Complete concept development for focal plane instrumentation for the optical telescope and X-ray telescope.
Complete STEREO Phase A Plan: June 2000	Complete STEREO Phase A studies by 6/00, including release of an AO for investigations with specific instruments and selection of the formulation phase payload.
Deliver Solar-B Electrical Engineering Models Plan: September 2000	Complete and deliver for testing Solar-B's four Electrical Engineering Models (EEMs).

SEU

Release RFP for GLAST Technology Development Plan: 2nd Qtr FY 1998 Actual: 2nd Qtr FY 1998	Release RFP for critical technology for tracker, anticoincidence shield, calorimeter, and data acquisition subsystems. Completed on schedule.
Release RFP for Constellation X-ray Technology Development Plan: 2nd Qtr. FY 1998 Actual: 2nd Qtr. FY 1998	Release RFP for critical technology development for hard X-ray telescope, Charge Coupled Device (CCD)/grating, and X-ray calorimeter. Completed on schedule.
FIRST Composite Mirror Plan: 4th Qtr. FY 1998 Actual: 4th Qtr. FY 1998	Demonstrate 2-meter class composite mirror with surface smoothness less than or equal to 2.4 microns RMS. Completed on schedule.
FIRST Technology Development Plan: 4th Qtr. FY 1999	Develop Key Technologies in the area of cryo coolers, mixers, bolometer arrays, and light weight 3.5 m telescope to prepare for C/D start in FY 2000 and launch in FY 2006.
STEREO: Complete Concept Definitions Plan: 4th Qtr. FY 1999	Complete preliminary concept definitions for spacecraft systems and instruments through peer reviewed NRAs.

FIRST instrument performance Plan: FY 2000	Demonstrate performance of the Superconductor-Insulator-Superconductor mixer to at least 8hv/k at 1120 GHz and 10hv/k at 1200 GHz. The U.S. contribution to the ESA Far Infared Space Telescope (FIRST) is the heterodyne instrument, which contains the SIS receiver.
GLAST prototype instrument performance – FY 2000	The prototype primary instrument for GLAST will demonstrate achievement of the established instrument performance level; angular resolution of 3.5 degrees across the entire 20 MeV to 100 GeV energy range.

Flight Validation (New Millennium Program)

Deep Space 1

DS 1 Ship to KSC Plan: April 1998 Actual: July 1998	Ship to KSC launch site. Delayed three months due to technical problems. Resulted in 3-month slip to launch.
DS 1 Launch Plan: July 1998 Actual: October 1998	First New Millennium technology demonstration flight. Launched in October 1998, three months late due to development problems. Spacecraft has now met minimum success criteria for 4 of 5 mission-defining technologies and 2 of 7 mission-enhancing technologies.

Deep Space 2

DS 2 Ship TMM for Environmental Test Plan: January 1998 Actual: January 1998	Ship thermal mass model for environmental testing with the Mars Surveyor 98 Lander Cruise Stage Spacecraft.
DS 2 Probe Ship to KSC Plan: October 1998 Actual: November 1998	Probe will be shipped to KSC for integration with Mars 98 Lander.
Launch DS 2 Plan: January 1999 Actual: January 1999	Piggyback on Mars 98 Lander.

Research Program

Space Science Research and Analysis

Issue NASA Research Announcement (NRA) Plan: February 1998 Actual: February 1998 Plan: February 1999 Actual: January 1999 Plan: February 2000	The OSS NRA for Research Opportunities in Space Science (ROSS) solicits proposals for basic SR&T investigations to seek to understand natural space phenomena and space related technologies across the full range of space science programs relevant to the four OSS science themes. Participation in this program is open to all categories of U.S. and non-U.S. organizations including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies. Minority and disadvantaged institutions are particularly encouraged to apply. Recommendations for funding are based on the evaluation of each proposal's science and technical merits, and its relevance to the OSS objectives as described in the NRA.

ACCOMPLISHMENTS AND PLANS

Core Technology Program

Space Science Core

The Explorer Technology initiative will identify, develop, infuse and transfer technologies that enable and enhance opportunities for frequent scientific investigations at the highest science value per unit cost. Procurement of the RAD6000 microprocessor chip in a multi-chip module format will enable a command and data handling "In Your Palm" Chip-on-Board technology demonstration to be incorporated in future SMEX missions. An Explorers NASA Research Announcement (NRA) was released in October 1998 and supports technology development in optical systems for instruments, data systems hardware and software, and guidance navigation and control. Grantees will be selected in spring 1999.

The Information Systems program will continue to provide reliable access for research communities and the public to obtain science data through the Planetary Data System, National Space Science Data Center, Space Telescope Science Institute, and High Energy Astrophysics Science Archive Research Center. Continuing advances in development and infusion of evolving information technology will increase the level of interoperability to support interdisciplinary research.

In High Performance Computing and Communication, the Remote Exploration and Experimentation project will continue to support the development of a first-generation testbed for scaleable spaceborne applications as well as embedded scaleable high-performance computers.

Science instrument development will continue to develop initial technologies for new sensors, detectors, and other instruments in support of specific space science research objectives. In many cases these technologies will be flown and validated as part of the suborbital program, either on balloons or rockets.

Planetary flight support will continue to develop the Advanced Multi-mission Operations System ground system upgrade, which will enable greater efficiency in the monitoring of spacecraft systems. This will allow us to continue to operate at a reduced level of overall mission operations costs.

Cross-Enterprise Technology

Activities within the Cross-Enterprise Technology program continue to focus on reducing spacecraft size, weight, and operating costs.

The Advanced Power and On-Board Propulsion Thrust Area developed the fundamental technology for the New Millennium Program's DS 1 ion propulsion system. The system started operation on November 24th, 1998. The Scarlett solar concentrator array, developed jointly with the Air Force Research Laboratory, was also successfully deployed on DS 1. Plans in this area include continued pursuit of performance improvements in multi-bandgap solar cells and NiMH and Lithium batteries. The use of titanium ion extraction grids is also being investigated as an alternate approach to provide a low-cost, low-risk, longer-life ion extraction system necessary for the next-generation of deep space science missions.

In the Sensors and Instrument Component Technology Thrust Area, accomplishments include a five-fold sensitivity improvement of low-cost, ultra-uniform, quantum infrared detectors for astronomical and infrared imaging applications. A demonstration utilizing a miniaturized precision micro-electronics/mechanical systems (MEMS) hygrometer flew in Atlantic Hurricane Bonnie on the NASA DC8, providing high-resolution, real-time humidity data to report and help predict the hurricane's movement and structure. Another demonstration featured a new low-cost (and size) MEMS micro-weather station as well as a sub-millimeter MEMS mixer. These new systems will now allow upper atmospheric sensing satellites to measure global chemical structure, composition and changes with higher fidelity to improve ozone prediction efforts. Work will continue on the development of lightweight structures and thin-film active arrays for high performance Synthetic Aperture Radar (SAR), which will dramatically reduce the projected fabrication cost and mass of these radar components.

A highlight in the Distributed Spacecraft thrust area was the completion of the integration and laboratory characterization of the Programmable Intelligent Micro-tracker (PIM) using an Active Pixel Sensor detector. The PIM represents a key component of the integrated high-performance guidance, navigation, and control (GN&C) capability required for precision formation flying and spacecraft constellation control. Other advances in development of GPS-based sensors for navigation and multi-spacecraft control algorithms will be built upon to validate an integrated operational capability.

High-Rate Data Delivery produced a software architecture for 4-kHz image acquisition from the Digital Integrated Camera Experiment (DICE) to be used for optical communications acquisition and tracking. Also, the hardware assembly of a 980 nano-meter boresight laser for the 1550 nano-meter Laser Transmitter Breadboard (LLBB) was completed, a key component for the development of an operational laser communications capability. Developments will continue for both near-Earth and deep space RF communications, including new traveling wave tube (TWT) and solid-state power amplifier components, phased-array antenna developments, and propagation models used by both the government and commercial communications sectors.

The Micro/Nano Spacecraft thrust area continued to focus developments on low-power and higher density electronics, and miniaturization of spacecraft subsystem components, such as MEMS propulsion. A holographic memory was successfully tested and demonstrated the potential for radiation-resistant on-board terabyte storage components in the next decade. Continued advancements in low-power, low-voltage VLSI circuits promise higher performance while significantly reducing both avionics and power component mass on spacecraft. Developments in adaptation of commercial processors for space use (including radiation hardening) will continue, emphasizing the use of proven designs to reduce development costs for the next generation of spacecraft for both near-Earth and deep space missions.

Investigators in the Surface Systems thrust area formulated, implemented, and validated Mars Sample Return rover capability including non-line-of-sight navigation, traversal of forty meters with a single command, approach and rock acquisition with a single command, and rock coring. They also conceived and validated capability for autonomous dust removal using charge polarity reversal and electroactive polymer wipers in support of nanorover exploration of asteroids. The Sprint "flying eye" was successfully demonstrated as an astronaut assistant. In addition, the design, fabrication, and testing of an anthropomorphic arm, wrist, and fingers in support of large platform maintenance (e.g. ISS) was completed.

The New Millennium Program DS 1 launched on October 24, 1998 carrying two experiments developed by the Thinking Space Systems thrust. They are the Beacon Monitor Operations Experiment (BMOX) and the Remote Agent Experiment (RAX). BMOX demonstrates the operational concept for reduced telemetry tracking baselined for Europa, Pluto and other missions, and validates Artificial Intelligent-based software for onboard engineering data summarization and beacon signaling. RAX demonstrates an architectural approach to onboard autonomy applicable to many future missions and validates onboard planning and scheduling, goal-oriented, robust execution, and automated mode identification and reconfiguration.

In the Ultra-Lightweight Space Structures and Observatories area, work progressed on the development of large inflatable and membrane deployable structures. A 16-meter x 7-meter model of the Next Generation Space Telescope (NGST) inflatable sunshield was developed and successfully deployed on the ground at the ILC Dover facility. Also, an inflatable solar array and inflatable Synthetic Aperture Radar (SAR) experiment was selected for year 2000 flight, from a Space Inflatables Program solicitation. In addition, 14-meter inflatable rigidizable struts for solar sail applications were fabricated and successfully tested.

In the Next Generation Infrastructure thrust, the Smart Assembly Modeler (SAM) is now in beta testing. SAM assembles FEM models from independently created part or component FEM models, which are platform independent, and allows component design engineers to predict and assess component performance when integrated into a real system.

In FY 2000 work will commence on three new items in the Cross-Enterprise Technology program: self-sustaining robotic networks, gossamer spacecraft, and next decade planning. Self-sustaining robotic networks will begin development of technologies necessary to extend ongoing advances in spacecraft automation and miniaturization to enable self-tasking, self-repairing, evolvable networks of small, highly mobile rovers for "virtual presence" planetary science and exploration in challenging environments. Gossamer spacecraft will begin developing ultralight structures and other technologies required to demonstrate the deployment, control, and utility of thin-film deployable structures. Next decade planning will support the development and refinement of concepts and technologies that are critical to developing a robust set of civil space initiatives during the FY 2001 to FY 2010 timeframe. Examples of concepts that will be addressed by this initiative include human space flight beyond low-earth orbit, enabling a self-sustaining commercial space activity, and enabling the direct involvement of the public in space exploration.

Focused Programs

The Astronomical Search for Origins focused program will fund mission design and technology development for six elements in FY 1999 and 2000:

- An interferometry technology validation flight (New Millennium Space Technology-3; formerly included in the flight validation program) to demonstrate the concept of separated spacecraft interferometry. This 6-month flight demonstration, scheduled for launch in 2002, will utilize two spacecraft to validate precision formation flying and space interferometry. This activity has been transferred from the flight validation program to the Astronomical Search for Origins focused program since its purpose is to validate those technologies required for the Terrestrial Planet Finder mission (see below).

- Space Interferometer Mission (SIM) will be the world's first long-baseline operational optical space interferometer. It is scheduled for launch in FY 2005, assuming successful technology development. This mission has dual objectives: science and technology. The science objectives include astrometric detection of planets around other stars in our galaxy (mostly those of Uranus' mass but also some as small as several Earth masses), and precision location of very dim stars to an unprecedented accuracy: SIM will be a factor of 250 better in accuracy on stars 1000-times fainter than the best catalog currently available. The technology objective is to serve as the precursor to the future interferometry-based TPF mission. Specific technologies to be developed include precision laser metrology, controlled optics, optical delay lines, vibration isolation and structural quieting systems, and deployable structures.

- Next Generation Space Telescope (NGST) will combine large aperture and low temperature in an ideal infrared observing environment. NGST will allow astronomers to study the first protogalaxies, the first star clusters as they make their first generation of stars, and the first supernovae as they release heavy chemical elements into the interstellar gas. New technologies include precision-deployable structures, very large, low-area-density cold mirrors and active optics, and low-noise, large format infrared detectors. The target launch date is FY 2007.

- Keck Interferometer Phase 1enables NASA to capitalize on its significant previous investment in the Keck Observatory in Hawaii by connecting Keck's twin 10-meter telescopes into an 85-meter-baseline interferometer. At the time of Phase 1 completion in FY 2000, the Keck interferometer will become the world's most powerful ground optical instrument. Keck will be able to directly detect hot planets with Jupiter-size masses and will also be able to characterize clouds of dust and gases permeating other planetary systems. Phase 2 will add four 1.8-meter outrigger telescopes to the interferometer complement which will allow astrometric detection of Uranus-sized planets and will provide the capability to image protoplanetary discs. Phase 2 is planned to be completed in FY 2002

- Terrestrial Planet Finder (TPF) is aimed at the ultimate goal of the NASA's Origins program: to find Earth-like planets. Each of the precursor Origins activities, including the Space Infrared Telescope Facility (SIRTF), provides knowledge and technology needed for the design of the TPF. As currently envisioned, TPF will either be a large single-spacecraft interferometer or a group of several spacecraft (possibly copies of NGST) flown in precise formation. Thus, the experience and understanding gained in each step of the Origins program will be needed to make TPF successful.

- The Optical Interferometry Laboratory at the Jet Propulsion Lab will enable the development and verification of interferometry systems operating at the extremely high levels of precision required to meet the objectives of the Origins program. The new facility will include a high bay, a low bay, a ground support equipment room and three development laboratories. The budget includes Construction of Facilities funding of $2.5 million per year in FY 1999 and FY 2000 for this facility.

The Advanced Deep Space Systems focused program will continue to provide for the development, integration, and testing of revolutionary technologies for solar system and outer planetary exploration in FY 1999-2000. Technologies developed in this area will also support a Solar Probe mission (see below), which utilizes many of the same systems and technologies as Europa and Pluto/Kuiper. The primary focus of the Deep Space technology developments is to reduce the mass and volume of planetary spacecraft, toward the goal of a "spacecraft on a chip."

Key technology partnerships will be maintained with national laboratories and research agencies such as:
- Air Force Research Labs to develop radiation-hard microelectronics technology
- Sandia and Los Alamos National Laboratory to support MEMS, and ARPS technology;
- MIT Lincoln Labs to continue Advanced Semiconductor technology; and DARPA to continue ultra-scale computing and quantum computing technology.

Emphasis will be on micro-avionics, autonomy, computing technologies, and advanced power systems. The Advanced Radioisotope Power Source (ARPS) activity will begin to develop a robust high-efficiency, low-mass, low-cost 100-watt-class electrical power source for deep space missions in FY 1998, and will develop advanced technologies for radioisotope power sources in the milliwatt and 10-watt class for future science missions. This activity, performed in partnership with NASA/JPL and the Department of Energy (DoE), will: increase the efficiency of thermal to electric converters; reduce the cost and time to fabricate, test and deliver flight ARPS for deep space missions; and provide breakthrough technology and/or multifunctional radioisotope power sources for future microspacecraft.

Since FY 1998, the Center for Integrated Space Microsystems (CISM) has been developing the advanced computing and avionics technologies that will enable miniaturized autonomous robotic spacecraft for deep-space exploration. These technologies will comprise the core of the advanced spacecraft development. A world-class facility for microelectronics system design, advanced simulation, rapid prototyping, and integration and test is being established at JPL in FY 1999. This facility will be electronically linked to industrial partners and collaborating universities as part of the distributed Collaborative Engineering Workbench technology.

Mission planning will support design and definition of the Europa Orbiter mission, targeted for launch in FY 2003, and the Pluto/Kuiper Express mission in FY 2004. Advanced Deep Space Systems also includes funding for the Champollion/Comet Lander mission, which has been transferred from the Flight Validation Program (where it was referred to as the New Millennium Program Deep Space-4 (Now Space Technology-4) mission), because it is a solar system exploration mission.

The focus for Sun-Earth Connections mission planning and technology activities will be directed toward the following future missions:

- Solar-B, a joint mission with the Japanese (ISAS spacecraft and launch), consists of a coordinated set of optical, EUV, and X-ray instruments that will apply a systems approach to the interaction between the Sun's magnetic field and its high temperature, ionized atmosphere. Technologies required by this mission include lightweight, stable optics and high-accuracy polarimetry for high-resolution (~0.1 arc sec) measurements of solar magnetic fields. Solar-B's expected launch date is FY 2004.

- STEREO is conceived as two smallsats in solar orbit. These spacecraft are to provide stereo imaging of solar corona, track solar mass ejections from the Sun to Earth using radio and optical instruments, and measure in-situ the solar wind and energetic particles (solar mass ejections appear to be a primary source of intense solar energetic particles events). STEREO's anticipated launch date is in FY 2004. However, OSS is reviewing options to accelerate this schedule, given Congressional interest.

- Solar Probe, the first close fly-by of a star (within 4 solar radii), requires a thermal shield to protect the payload from the Sun without releasing material that would contaminate the in-situ measurements. Because of its deep space flight trajectory, Solar Probe also requires many of the technologies being developed within the Advanced Deep Space Systems focused program, such as radiation hardening for the Jupiter swing-by and fly-by the Sun. The target launch date is FY 2007.

- Magnetospheric Multiscale is to be comprised of six spacecraft (four for in-situ measurements, two for global imaging) to study simultaneously the global behavior of the magnetosphere and the magnetospheric processes at the small scales where many of the basic interactions occur.

- Global Electrodynamics is a mission made up of five spacecraft, which will have an "atmospheric dipping" capability for investigating the electromagnetic coupling between the solar wind and upper atmosphere.

- Magnetospheric Constellation will support a fleet of 10-100 microsats using radio tomography and in-situ instrumentation to provide instantaneous global maps of plasma and field structures in the magnetosphere.

Structure and Evolution of the Universe mission planning and technology activities focus on development and demonstration of technologies necessary to implement the space missions outlined in the recent SEU Science and Technology Roadmaps. The priority missions include:

- Gamma Ray Large Area Space Telescope (GLAST). GLAST will study cosmic sources of high-energy particles and radiation (up to 300 GeV) with a large area, wide field-of-view, imaging telescope, using solid-state particle tracking technology. This technology is being developed in cooperation with DOE.

- ESA's Far Infrared and Submillimeter Space Telescope (FIRST). The U.S. participation on the FIRST mission substantially enhances the science goals with four key technologies: lightweight telescopes, cryocoolers, bolometer arrays, and heterodyne receivers.

- Constellation X-ray Mission. Constellation will use multiple satellites to enable a very large collecting area. Each spacecraft will be equipped with a high-throughput telescope for the low-energy band up to 10 keV, and three grazing-incidence telescopes for the high-energy band.

Flight Validation (New Millennium Program)

The DS-1 spacecraft successfully launched in 1998 and has partially validated four of the five mission-defining technology demonstrations. These technologies will complete their validation by the end of FY 1999. Validation of the remaining mission-defining technology, the miniature imaging camera spectrometer, awaits arrival at the relevant environment, an asteroid. The demonstration of the ion engine was especially important not only because it enables new destinations for science missions at lower cost than chemical propulsion, but also because it is planned for use in several U.S. commercial communications constellations in the near future.

The DS-2 mission also successfully launched piggyback on the Mars 98 Polar Lander in January 1999. This mission will arrive at Mars in December 1999, at which time the two DS-2 basketball-sized aeroshells will crash into the Martian surface at about 200 meters per second. Shattering on impact, each aeroshell will release a miniature two-piece science probe that will punch into the soil to a depth of up to two meters. The microprobes' primary science goal is to determine if water ice is present in the Martian subsurface- an important clue to the puzzle of whether life exists, or ever existed, on Mars. The tiny science stations will also measure soil temperature and monitor local Martian weather.

In keeping with the focus of the New Millennium Program (NMP) on providing flight validation of broadly applicable technologies, the NMP Space Technology-3 mission has been moved to the Astronomical Search for Origins focused program. ST-3 will validate technologies to benefit future interferometry missions such as Terrestrial Planet Finder. Similarly, the Space Technology-4 mission (Champollion/Comet Lander) has been moved to the Deep Space Systems focused program, since this mission to land on the surface of a comet benefits the objectives of the Solar System Exploration scientific theme.

Over the next several months, in addition to selecting the ST-5 mission, the Office of Space Science will undertake a thorough review of the New Millennium Program in order to assess the NMP's objectives, structure, management, and relationship to overall OSS goals. The intent is to ensure that the NMP is properly postured (in the ST-5 and post-ST-5 timeframe) to maintain its emphasis on technology validation, risk mitigation, and rapid infusion of technology into science missions.

Research

Research and Analysis

Our R&A program continued to produce exciting scientific results in FY 1998. NASA astronomers discovered what appears to be the clearest evidence yet of a budding solar system around a nearby star. An image from the Keck II telescope in Hawaii reveals the probable site of planet formation around the star HR 4796. The image shows a swirling disk of dust around the star, which is about 220 light-years from Earth in the constellation Centaurus. Within the disk is a telltale empty region that may have been swept clean when material was pulled into newly formed planetary bodies. It has been postulated that this may be what our solar system looked like at the end of its main planetary formation phase.

Research continues on the Martian Meteorite ALH84001 with most findings pointing to a non-life origin of many of the features. However, there are still several lines of mineralogical evidence that may point to life processes (e.g., origins of some of the iron oxides). Major new research tools that detect biomarkers (e.g., a new technique to use iron isotopes to indicate life activities) have been developed over the past year. These tools are being perfected and will be applied to the meteorite this year. In addition, a team of scientists has made their annual trek to the Antarctic to search for meteorites, particularly for other ancient Martian meteorites.

To coordinate our efforts to detect, track and characterize potentially hazardous asteroids and comets that could approach Earth, a new program office has been established at the Jet Propulsion Laboratory. The Near-Earth Object Program Office will focus on the goal of locating at least 90 percent of the estimated 2,000 asteroids and comets that approach the Earth and are larger than about 2/3-mile (about 1 kilometer) in diameter, by the end of the next decade. These are objects that are difficult to detect because of their relatively small size, but are large enough to cause global effects if one hit the Earth. In addition to managing the detection and cataloging of near-Earth objects, the new NASA office will be responsible for facilitating communications between the astronomical community and the public should any potentially hazardous objects be discovered as a result of the program. Science research solicitations and resulting peer reviews, international coordination, and strategic planning regarding future missions will remain the responsibilities of NASA Headquarters.

In recognition of the interrelationship between the origin and evolution of life and the origin and evolution of planets, a new program within the framework of Astrobiology was initiated in 1997. A multi-disciplinary Astrobiology Institute has been established with members from 11 geographically distributed research institutions, linked through advanced telecommunications. Examples of research accomplishments for the past year include the demonstration that the synthesis of protein-forming amino acids is more favorable in submarine hydrothermal systems than in surface seawater, suggesting a pre-biotic "nursery" for the origin of life on Earth. An analysis of the geologic record shows that the same evolutionary processes affecting the biotic transitions during "normal" times are not fundamentally different from processes operating during times of mass extinctions. And modeling of the heat pulses from large impactors hitting either early Mars or Earth suggests that life would have had an easier time surviving on Mars than Earth.

Data Analysis

NASA's Space Science spacecraft continue to generate a stream of scientific discoveries. Many of these findings are of broad interest to the general public, as witnessed by widespread media coverage. Recent highlights include results from Galileo, Hubble Space Telescope, Mars Global Surveyor, Lunar Prospector, and the Compton Gamma-Ray Observatory; however, many other Space Science spacecraft have been "in the news" and extremely scientifically productive as well. NASA is also finding ways to partner with the education community in order to strengthen science, technology, and mathematics education. Listed below are the top science stories of the past year from NASA Space Science missions, as selected by the Science Directors and Associate Administrator of Space Science at NASA Headquarters.

- HUBBLE GOES TO THE LIMIT IN SEARCH OF FARTHEST GALAXIES. The Hubble Space Telescope peered farther across space and further back into time than ever before, into a previously unseen realm of the universe. A "long exposure" infrared image taken with Hubble's Near Infrared Camera and Multi-Object Spectrometer (NICMOS) has uncovered the faintest galaxies ever seen, some of which could be over 12 billion light-years away, making them the farthest objects ever seen.

- POSSIBLE EXTRASOLAR PLANET DISCOVERED. The Hubble Space Telescope has given astronomers their first direct look at what may be a planet outside our solar system. Located 450 light-years away in the constellation Taurus, the object, called TMR-1C, is estimated to be 2-3 times the mass of Jupiter and appears to lie at the end of a strange filament of light. It is also possible that the object is a giant protoplanet or a brown dwarf star (a small star that has failed to sustain nuclear fusion).

- SHARPEST IMAGES OF MAGNETIC RECONNECTIONS ON SUN. Stunning detail in images from the Transition Region and Coronal Explorer (TRACE) spacecraft reveal the first detailed observations of a magnetic energy release, called a magnetic reconnection. The magnetic reconnection was observed on May 8, 1998, in a region of the solar atmosphere where two sets of perpendicular magnetic loops expanded into each other. Magnetic reconnection occurs when magnetic fields "snap" to a new, lower energy configuration, much like when a twisted rubber band unwinds or breaks. A magnetic reconnection can release vast amounts of energy and is responsible for explosive events on the Sun, such as flares, that can cause communication and power system disruptions on Earth.

- MASSIVE BLACK HOLE FEEDING FRENZY. The Hubble Space Telescope provided an unprecedented look at the nearest example of galactic cannibalism -- a massive black hole hidden at the center of the nearby giant galaxy Centaurus A that is feeding on a smaller galaxy in a spectacular collision. The suspected black hole is so dense it contains the mass of perhaps a billion stars, compacted into a small region of space not much larger than our Solar System. Such fireworks were common in the early universe, as galaxies formed and evolved, but are rare today. Blue clusters of newborn stars and silhouettes of dust filaments are interspersed with blazing orange-glowing gas. Hubble's infrared vision has penetrated this wall of dust for the first time to see a twisted disk of hot gas swept up in the black hole's gravitational whirlpool.

- GALILEO PROVIDES MAJOR SCIENCE AT JUPITER. Jupiter's second largest moon, Callisto, may have a liquid ocean tucked under its icy, cratered crust, according to scientists studying data from the Galileo spacecraft. Key similarities were noted between Callisto and another of Jupiter's moons, Europa, which has already displayed strong evidence of a subsurface ocean. The main evidence is that Callisto's magnetic field is variable like Europa's, which can be explained by the presence of varying electrical currents, associated with Jupiter, flowing near Callisto's surface; these electrical currents flow in opposite directions at different times lending further credence to the presence of a subsurface ocean. Also, Galileo data show that Jupiter's intricate swirling ring system is formed by dust kicked up as interplanetary meteoroids smash into the giant planet's four small inner moons. Galileo images also reveal that the outermost ring is actually two rings, one embedded within the other.

- TREMENDOUS GAMMA-RAY FLARE BLASTS EARTH. An intense wave of gamma rays, emanating from a catastrophic magnetic flare on a mysterious star 20,000 light years away, struck the Earth's atmosphere on August 27, 1998, providing important clues about some of the most unusual stars in the Universe. The wave of radiation emanated from a newly discovered type of star called a magnetar-- a dense ball of super-heavy matter, no larger than a city but weighing more than the Sun with the greatest magnetic field known in the Universe. It powers a steady glow of X-rays from the star's surface, often punctuated by brief, intense gamma-ray flashes, and occasionally by cataclysmic flares like the one on August 27. This blast was detected by several of our spacecraft.

- NEW TYPE OF STAR DISCOVERED. A neutron star, located 40,000 light years from Earth, is generating the most intense magnetic field yet observed in the Universe, confirming the existence of a special class of neutron stars dubbed "magnetars." Magnetars have a magnetic field estimated to be one thousand trillion times the strength of Earth's magnetic field (a neutron star is a burned-out star roughly equal in mass to the Sun that has collapsed to about 10 miles across). This finding should help scientists calculate the rate at which stars die and create the heavier elements that later become planets and other stars. The magnetic field generated by this star is so intense that it heats the surface to 18 million degrees Fahrenheit. Data from the Compton Gamma-Ray Observatory, Rossi X-ray Timing Explorer, and Advanced Spacecraft for Cosmology Astrophysics led to this discovery.

- ICE ON MOON CONFIRMED. There is a high probability that water ice exists at both the north and south poles of the Moon, according to NASA's Lunar Prospector. The poles of the Moon may contain up to six billion metric tons of water ice, and evidence suggests that water ice deposits of relatively high concentration are trapped beneath the soil in the permanently shadowed craters of both lunar polar regions. In addition, Lunar Prospector found strong evidence that the Moon has a small, iron-rich core.

- BACKGROUND INFRARED GLOW TO UNIVERSE DISCOVERED. Astronomers using data from NASA's Cosmic Background Explorer (COBE), launched in 1989, made the first definitive detection of a background infrared glow across the sky produced by dust warmed by all the stars that have existed since the beginning of time. The telltale infrared radiation puts a limit on the total amount of energy released by all the stars in the universe. Astronomers say this will greatly improve development of models explaining how stars and galaxies were born and evolved after the Big Bang. The discovery reveals that a surprisingly large amount of starlight in the universe cannot be seen directly by today's optical telescopes, perhaps due to stars being hidden in dust, or being too faint or far away to be seen.

- LARGEST EXPLOSION SINCE BIG BANG. A recently detected cosmic gamma ray burst released a hundred times more energy than previously theorized, making it the most powerful explosion observed since the creation of the universe in the Big Bang. Scientists say that for about one or two seconds, this burst, which originated at about 12 billion light years from the Earth, was as luminous as all the rest of the entire universe. The burst appears to have released several hundred times more energy than a supernova, until now the most energetic known phenomenon in the universe. Finding such a large energy release over such a brief period of time is unprecedented in astronomy, except for the Big Bang itself.

- LATEST FROM MARS -- A warmer, wetter past. NASA's Mars Global Surveyor and Mars Pathfinder spacecraft suggest that the planet may have had thermal activity and was awash in water in its early history three billion to 4.5 billion years ago. Magnetized dust particles and the possible presence of conglomerates of smaller rocks, pebbles and soil suggest copious water in the distant past. In addition, the bulk of the Pathfinder landing site appears to have been deposited by large volumes of water, and the hills on the horizon known as Twin Peaks appear to be streamlined islands shaped by water. The first clear evidence of an ancient hydrothermal system implies that water was stable at or near the surface and that a thicker atmosphere existed in Mars' early history.

- SOLAR QUAKES. Scientists have observed for the first time that solar flares produce seismic waves in the Sun's interior that resemble those created by earthquakes. A moderate-sized flare on July 9, 1996, observed by the NASA/ESA Solar and Heliospheric Observatory (SOHO) spacecraft, generated a solar quake that contained about 40,000 times the energy released in the great 1906 earthquake that devastated San Francisco. The amount of energy released was enough to power the United States for 20 years at its current level of consumption, and was equivalent to an 11.3 magnitude earthquake.

- EXPANDING UNIVERSE. In Science magazine's top research advance of 1998, two international teams of astronomers provided a glimpse into the destiny of the universe when they looked at distant galaxies and found that they were rushing apart at an accelerating rate. Scientists discovered decades ago that the universe has been expanding since the Big Bang. But whether the gravitational pull between galaxies could slow - and ultimately reverse - that expansion has been unknown. This year's discovery showed that the expansion of the universe is in fact speeding up. This implies that gravity is no match for the force that is pushing the universe outward in all directions and that the expansion may continue, perhaps indefinitely. While the National Science Foundation funded much of the ground-based research behind these studies, data from NASA's Hubble Space Telescope and from ROSAT also played a crucial role.

BASIS OF FY 2000 FUNDING REQUIREMENT

SUBORBITAL PROGRAM

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Balloon program	13,700	13,500	13,500
Sounding rockets	24,655	29,600	24,000
Total	38,355	43,100	37,500

PROGRAM GOALS

The principal goal of the Suborbital program is to provide frequent, low-cost flight opportunities for space science researchers to fly payloads to conduct research of the Earth's ionosphere and magnetosphere, space plasma physics, astronomy, and high energy astrophysics. The program also serves as a technology testbed for instruments which may ultimately fly aboard orbital spacecraft, thus reducing cost and technical risks associated with the development of future space science missions. It is also the primary program for training graduate students and young scientists in hands-on research techniques.

STRATEGY FOR ACHIEVING GOALS

The Suborbital program provides the science community with a variety of options for the acquisition of in-situ or remote sensing data. Aircraft, balloons and sounding rockets provide access to the upper limits of the Earth's atmosphere. Activities are conducted on both a national and international cooperative basis.

The Balloon program provides a cost-effective way to test flight instrumentation in the space radiation environment and to make observations at altitudes above most of the water vapor in the atmosphere. In many instances, it is necessary to fly primary scientific experiments on balloons, due to size, weight, cost considerations or lack of other opportunities. Balloon experiments are particularly useful for infrared, gamma-ray, and cosmic-ray astronomy. In addition to the level-of-effort science observations, the program has successfully developed balloons capable of lifting payloads greater than 5000 pounds. Balloons are now also capable of conducting a limited number of missions lasting 9 to 24 days, and successful long-duration flights are being conducted in or near both polar regions. The Balloon program is managed by the GSFC Wallops Flight Facility (WFF). Flight operations are conducted by the National Scientific Balloon Facility (NSBF), a government-owned, contractor-operated facility in Palestine, Texas.

Analytical tools have been developed to predict balloon performance and flight conditions. These tools are being employed to analyze new balloon materials in order to develop an ultra-long-duration flight capability (approximately 100 days), based on super-pressure balloons. An integrated management team has been established to develop and test the balloon vehicle and balloon-craft support system.

Sounding rockets are uniquely suited to perform low-altitude measurements (between balloon and spacecraft altitude) and to measure vertical variations of many atmospheric parameters. The sounding rocket program supports special areas of study, such as: the nature, characteristics and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including aurora production of and energy coupling into the atmosphere; and the nature, characteristics and spectra of radiation of the Sun, stars and other celestial objects. In addition, the sounding rocket program allows several science disciplines to flight test instruments and experiments being developed for future flight missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. The program is managed by GSFC/WFF, and launch operations are conducted from facilities at WFF, Virginia; White Sands, New Mexico; and Poker Flat, Alaska, as well as occasional foreign locations. A performance-based contract was awarded in December 1998, in order to allow the government to transition away from operational control.

In an effort to broaden the education opportunities using experiments built by students and flown on suborbital rockets and stratospheric balloons, a Student Launch Program has been established for U.S. institutions of higher learning. This program offers students for the bachelor's through master's degrees an opportunity to work on a reasonably complex project from its inception to its end, in a timeframe tenable within their academic careers. A NASA Research Announcement released in June 1996 offered proposers up to $35,000 over 30 months or less for the design, construction, and flight of student-built balloon and/or sounding rocket experiments, including analysis of data. Six proposals were accepted during the proposal review in 1997. The selected experiments will be flown during 1998 and 1999. NASA expects to continue this program with release of a new research announcement in FY 1999.

The Spartan program provides reusable spacecraft, which can be flown aboard the Shuttle. These units can be adapted to support a variety of science payloads and are deployed from the Shuttle cargo bay to conduct experiments for a short time (i.e. several hours or days). Payloads are later retrieved, reinstalled into the cargo bay and returned to Earth. The science payload is returned to the mission scientists for data retrieval and possible refurbishment for a future flight opportunity. The Spartan carrier is also refurbished and modified as needed to accommodate the next science payload. A Spartan payload flew during the recent STS-95 (John Glenn) mission.

SCHEDULE & OUTPUTS

Balloon Program

FY 1998	28 flights were planned from Palestine, Texas, Fort Sumner, Canada, Alaska, and Brazil. 26 flights were attempted, and 25 missions flew successfully.
FY 1999	31 flights are planned.
FY 2000	Based on an overall goal of conducting 26 world-wide science and technology demonstration balloon missions, at least 23 campaigns shall successfully achieve altitude and distance and investigators' instrumentation shall function as planned for at least 19 missions.

Sounding Rockets

FY 1998	21 flights were launched from WFF, WSMR, and Puerto Rico. All flights and science missions were completely successful.
FY 1999	37 flights are planned, including 7 from Poker Flat, 7 from Norway, and 1 from Sweden.
FY 2000	Based on an overall goal of successfully launching 25 sounding rocket missions, at least 23 payloads shall successfully achieve their required altitude and orientation and at least 21 investigators shall achieve their minimum mission success goals

Spartan

FY 1998	Spartan 201-4 was deployed and retrieved on STS-87 in December 1997.
FY 1999	Spartan 201-5 was deployed and retrieved on STS-95 in November 1998.

ACCOMPLISHMENTS AND PLANS

In FY 1998, 25 balloons were flown for the core program of which 24 were successful flights. Of that number, 21 met their science success criteria. Capping years of technology development, the ultra-long duration ballooning (ULDB) capability has been repeatedly demonstrated and is now fully operational. Collaboration work with JPL was also initiated in order to identify technologies for ULDB that could be useful for planetary exploration programs such as Mars. The first demonstration of a 3mcf super-pressure balloon is planned for March 1999 with a full flight demonstration (extended global circumnavigation) in FY 2000.

The sounding rocket program achieved 100% flight and science success in FY 1998. Additionally, an active campaign in Puerto Rico occurred during this period. Work on the sounding rocket operations procurement resulted in announcement of an award in December 1998. FY 1999 will represent a very ambitious flight year, concurrent with transition to a new approach toward managing the program.

The Spartan 201-04 unsuccessfully deployed on STS-87 was reflown as 201-05 in November 1998. This mission was a complete success and demonstrated a new communication system for future Spartans. The mission also provided real-time solar imagery, which was transmitted over the internet. Work continues on advanced carriers, which could support Explorer missions, environmental science initiatives, as well as Space Station free-flyers.

BASIS OF FY 2000 FUNDING REQUIREMENT

LAUNCH SERVICES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Launch services	27,600	--	--

The Launch Service budget has been distributed to the individual missions noted above. The FY 1998 funding reflects:

- Funding to complete payments for the launch of Cassini in October 1997 ($7.1 million). This funding is displayed here because there is no display for Cassini in this budget.
- Funding for multi-mission support such as engineering analysis and launch site operations and maintenance that was included in the Space Science FY 1998 Operating Plan and cannot be distributed to individual missions. After FY 1998, multi-mission support was moved to the Expendable Launch Vehicle Mission Support budegt line in the Payload Utilization and Operations section.

SCIENCE, AERONAUTICS, AND TECHNOLOGY APPROPRIATION

LIFE AND MICROGRAVITY SCIENCES & APPLICATIONS

FY 2000 CONGRESSIONAL BUDGET ESTIMATE

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Advanced Human Support Technology (AHST)	18,088	24,500	29,200	SAT 2-7
[Construction of facilities]	[2,200]			
Biomedical Research & Countermeasures (BR&C)	41,542	59,700	53,000	SAT 2-10
Gravitational Biology and Ecology (GB&E)	28,870	40,900	38,600	SAT 2-13
Microgravity Research (MR)	100,400	113,700	111,400	SAT 2-16
Space Product Development (SPD)	12,900	15,400	14,400	SAT 2-19
Occupational Health Research (OHR)	830	900	1,100	SAT 2-22
Space Medicine Research (SMR)	6,670	6,700	7,100	SAT 2-24
Mission Integration (MI)	4,900	1,700	1,400	SAT 2-27
Total	214,200	263,500	256,200	
Distribution of Program Amount by Installation				
Johnson Space Center (JSC)	55,718	75,800	73,200	
Kennedy Space Center (KSC)	5,330	5,000	3,800	
Marshall Space Flight Center (MSFC)	50,800	65,800	65,500	
Ames Research Center (ARC)	25,000	34,600	32,700	
Langley Research Center (LaRC)	400	200	0	
Glenn Research Center (GRC)	34,800	37,400	38,000	
Goddard Space Flight Center (GSFC)	10,500	9,100	6,100	
Jet Propulsion Laboratory (JPL)	13,200	13,800	14,300	
Headquarters (HQs)	18,452	21,800	22,600	
Total	214,200	263,500	256,200	

GENERAL

The Life and Microgravity Sciences and Applications (LMSA) program is an integral component of NASA's Human Exploration and Development of Space (HEDS) Enterprise. The projects, supported by the LMSA program, through ground - and space-based basic and applied research, seek to advance scientific and commercial knowledge, to enable the development of space for human enterprise, to create new products and services through space research, and to transfer the knowledge and technologies developed as broadly as possible within the United States. We seek to enable and exploit the possibilities of human space flight to improve the quality of life for people on Earth.

PROGRAM GOALS

The Office of Life and Microgravity Sciences and Applications (OLMSA) plays a primary role in the pursuit of the following goals and objectives of HEDS and a secondary role in the pursuit of other HEDS goals. OLMSA provides key products for the following four general goals of the enterprise.

Goal: Explore the role of gravity in physical, chemical, and biological processes

Objective- Enable the research community to use gravity as an experimental variable.

Goal: Continue to open and develop the space frontier

Sub-Goal: Develop and assemble the International Space Station (ISS) and utilize it to advance scientific, exploration, engineering and commercial activities.

Objective - Ensure the health, safety and performance of space flight crews.

Goal: Prepare to conduct human missions of exploration

Objective -- In partnership with the Space Science Enterprise, carry out an integrated program of robotics exploration of the solar system to characterize the potential for human exploration and development.

Goal: Aggressively seek investment from the private sector

Sub-Goal: Increase the affordability of space operations through privatization and commercialization.

Objective - Foster consortia of industry, academia, and government; leverage funding, resources, and expertise to identify and develop space commercial opportunities.

Objective - Share HEDS knowledge, technologies and assets that promise to enhance the quality of life on Earth.

Outcomes:

OLMSA seeks to advance scientific knowledge, to enable the development of space for human enterprise, and to transfer the knowledge and technologies that we develop as broadly as possible. We seek to enable and exploit the possibilities of human space flight and to improve the quality of life for people on Earth. Among the ultimate outcomes of our work are:

expanded fundamental knowledge;
improved health on earth and in space;
improved industrial processes;
expanded commercial activity in space; and
enhanced capabilities for humans to live, work and explore in space.

STRATEGY FOR ACHIEVING GOALS

OLMSA pursues the goals described above through the following projects, which focus on specific fields of research:

Advanced Human Support Technology (AHST)
- Provides cutting edge technologies for the support of humans in space.

Biomedical Research and Countermeasures (BR&C)
- Promotes the health, safety and performance of space crews.
- Investigates the biomedical effects of space flight to provide the biomedical basis for future human exploration and development of space.

Gravitational Biology and Ecology (GB&E)
- Investigates the interaction between gravity and basic biological processes using living systems, ranging from simple cells to humans, in space and on the ground.

Microgravity Research (MR)
- Uses the environment of space to explore the nature of physical, chemical, and biological processes contributing to progress in science and technology on Earth.
- Studies the role of gravity in technological processes, building a scientific foundation for understanding the consequences of gravitational environments beyond Earth's boundaries.

Space Product Development (SPD)
- Facilitates the use of space for commercial products and services.

Within each of these projects, OLMSA supports fundamental and applied research driven by an emphasis on expanding scientific and commercial knowledge and disseminating the research database as widely as possible to the American research and technology community. Mission driven research improves knowledge and technology for human space flight and exploration; and applications driven research seeks to transfer knowledge, expertise and technology to an appropriate partner or partners.

In addition, OLMSA is an operational organization conducting the following functions:

Space Medicine Research (SMR)

- Provides guidance to the operational medicine community at JSC for the delivery of clinical care in support of human space flight.
- Establishes requirements for medical care and medical research to support human space flight.

Occupational Health Research (OHR)

- Ensures health and safety of all NASA employees.

Mission Integration (MI)

- Integrates research missions involving human space flight.

OLMSA's program of research and technology development relies upon broad participation by researchers from academia, other government agencies and departments, nonprofit and commercial sectors, NASA's Commercial Space Centers (CSCs), NASA Specialized Centers for Research and Technology, and NASA Field Centers. In selecting investigations and projects for support, and ultimately for access to space, OLMSA follows different, but closely related processes for scientific research, for commercial research, and for technology research and development.

Scientific research uses ground-based research to find and refine concepts for space experiments and to create a framework of knowledge and expertise in which the full scientific value of space experiments can be realized. It utilizes the nation's academic and industrial resources, joining prominent researchers with NASA expertise in multidisciplinary microgravity experimentation. In support of the science community, the program also finances unique gravitational simulation facilities such as centrifuges, parabolic aircraft, drop towers/tubes, and other specialized support facilities and technologies such as chambers, bed rest studies, and data archiving. All non-commercial research is conducted on an open, competitive, peer-reviewed research solicitation process including the regular release of NASA Research Announcements (NRAs) in specific disciplines and reviews of proposals by independent panels of experts.

OLMSA implements its space-based research on robotic free-flying vehicles, Space Shuttle missions in which experiments use pressurized carriers (i.e. Spacelab, SpaceHab) and/or unpressurized carriers (i.e., IMPESS pallet, Hitchhiker or Get-Away-Special carriers) that fly in the cargo bay as well as the Shuttle Middeck for small payloads, and, in the future, on the ISS. OLMSA employs this array of flight platforms in support of the broader strategic goals enumerated above. OLMSA does not employ a separate research selection track for mission oriented research. It maintains a queue of worthy research, as opportunities become available.

OLMSA performance targets currently listed within the NASA FY 2000 Annual Performance Plan are as follows:
Goal: Explore the role of gravity in physical, chemical, and biological processes

Objective - Enable the research community to use gravity as an experimental variable

- Support an expanded research program of approximately 935 investigations, an increase of ~ 17% over FY 1999. Publish 100% of science research progress in the annual OLMSA Life Sciences and MR Program Tasks and Bibliographies and make it available on the Internet.
- Using suborbital rockets, complete one combustion experiment on the flame spread of liquid fuels to better control earth/space based fire hazards, and conduct one investigation to test theories of fundamental physics properties and physical laws of fluids to provide key data for earth and space-based processing materials; publish results in peer-reviewed open literature.
- Complete data reduction from the STS-95 Research Module mission. Begin to explore new cooperative efforts with the National Institutes of Health (NIH) in the area of aging and transfer space-derived research for industry development of a new drug to treat Chagas disease.

Goal: Continue to open and develop the space frontier

Objective - Ensure the health, safety and performance of space flight crews

- Develop medical protocols and test the capability of the Crew Health Care System (CHeCS) as integrated in the ISS U. S. Laboratory.
- Evaluate and develop for flight testing a minimum of three major research protocols intended to protect bone, muscle, and physical work capacity and prepare a minimum of 10 biomedical research experiments, utilizing the capabilities of the Space Transportation System (STS) and the ISS Human Research Facility (HRF) to study human responses to the gravitational environment, adding significantly to the general knowledge of these processes on earth.
- Complete the first phase (including outfitting of three test chambers) of the Advanced Life Support System Integrated Test Bed facility which will provide the capability to conduct a series of long duration, human in the loop, advanced technology tests over the next six years. Demonstrate key technology capabilities for human support such as advanced techniques for water processing using microbes, waste processing using biological degradation and fluidized bed incineration, a no-expendable trace gas contaminant control system, solid waste processing, and flight test a miniature mass spectrometer.
- Provide training to the appropriate NASA supervisors with specific emphasis on actions to prevent injury and illness on-the-job. Increase employee participation in the wellness program by at least 25% over the FY 1997 baseline. In coordination with the Office of Safety and Mission Assurance, achieve a 10% reduction in workers compensation claims over the FY 1998 baseline.

Goal: Prepare to conduct human missions of exploration

Objective -- In partnership with the Space Science Enterprise, carry out an integrated program of robotics exploration of the solar system to characterize the potential for human exploration and development

- Complete the Radiation Research Instrument for Mars 2001 mission to study transit, orbital and surface radiation effects and conduct three workshops to define and prioritize research tasks in subjects such as radiation shielding materials, in situ resource utilization and fluids management and heat transfer technology. Complete science definition of granular flows, flight and dust management experiments to begin gathering research data to alleviate critical problems of dust buildup, habitat foundation engineering and rover performance during planetary exploration.

Goal: Aggressively seek investment from the private sector

Sub-Goal: Increase the affordability of space operations through privatization and commercialization

Objective - Foster consortia of industry, academia, and government; leverage funding, resources, and expertise to identify and develop space commercial opportunities

- Utilize at least 30% of Space Shuttle and NASA's ISS FY 2000 capabilities for commercial investigations, per the U.S. Payload Utilization Plan (PUP).
- Establish up to two new Commercial Space Centers (CSCs).
- Foster the establishment of a telemedicine hub in Western Europe. NASA and the French Space Agency (CNES) will develop an international telemedicine program to incorporate and connect existing medical informatics capabilities into a user friendly commercial electronic telemedicine hub and apply lessons learned to human space flight.

Sub-Goal: Share HEDS knowledge, technologies, and assets that promise to enhance the quality of life on Earth

Objective – Involve our Nation's citizens in the adventure of exploring space and transfer knowledge and technologies to enhance the quality of life on Earth

- The NASA sponsored National Space Biomedical Research Institute (NSBRI) will conduct an open symposium relaying the results of space-oriented research activities focusing on up to 10 ground-related applications with the participation of interested investigators; publish results in a conference proceeding report.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED HUMAN SUPPORT TECHNOLOGY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Advanced Human Support Technology (AHST)	18,088	24,500	29.200

GOALS

The goals of AHST are: (1) to demonstrate and validate full self-sufficiency in air, water, and food recycling technology for use in space vehicles; (2) to demonstrate and validate integrated, fully autonomous environmental monitoring and control systems: and (3) to validate and incorporate human factors engineering technology and protocols to ensure maintenance of high ground and flight crew skills during Iong duration missions. AHST makes NASA technologies available to the private sector for Earth applications.

STRATEGY FOR ACHIEVING GOALS

AHST includes Advanced Life Support Systems (ALS), Space Human Factors (SHF), and Advanced Environmental Monitoring and Control (AEMC). ALS develops advanced regenerative life support technologies and systems by combining biological, physical. and chemical processes capable of producing and recycling the food, air, and water needed to enable long-term human missions in space in a safe and reliable manner while minimizing the need for resupply. SHF develops technologies that integrate the human and system elements of space flight and encourages mission planners to use human factors research results and technology developments to improve mission results and crew safety. AEMC develops new technologies, chemical and biological environmental sensors for air and water monitoring and microbial detection, as well as refining and micro miniaturizing currently available sensors.

Center Support

JSC is the lead center for AHST and coordinates all supporting center activities. JSC manages ALS facilities and conducts all system level integration and testing for ALS. KSC manages extramural research and conducts specific research tasks directed at using plants in ALS systems. The JPL is the lead for the AHST AEMC activities bringing their personnel and industry contacts to the development of sensors and monitoring capability. ARC manages extramural research and conducts specific research tasks directed at analytical models and physiochemical processes for ALS systems.

MEASURES OF PERFORMANCE

The actual data reported is based on interim information available as of mid-December 1998. Complete 1998 data will be available in February 1999 with publication of the 1998 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Number of Principal Investigations	40	47	71	70	77
Number of Co-Investigators Supported	80	90	140	138	152
Number of Refereed Publications	40	46	70	69	76

ACCOMPLISHMENTS AND PLANS

During FY 1998, the transfer of program management responsibility, including grants administration, continued from HQs to JSC. Accomplishments include: continued development of solid waste processing technology at ARC; mixed crop evaluations and continued development of the biological processing of solid wastes at KSC; completion of a 91-day, closed-chamber integrated physicochemical/biological life support systems test with four humans at JSC; and initiation of the ALS Systems Integration Test Bed Construction of Facility (CoF) project at JSC. Modification of the existing building foundation was accomplished on-schedule and two of the four Test Bed chamber facilities were delivered and installed. SHF accomplishments include: completion of the rapid prototyping laboratory for advanced displays and controls; completion of three separate SHF related evaluations during the 91-day chamber run; definition of interior architectural layouts for future chamber studies; and gathering of crew interaction data with restraints at glovebox workstations during a shuttle/spacelab flight. AEMC accomplishments include delivery of Electronic Nose for STS-95 flight experiment and the completion of Phase I for Wireless Augmented Reality Prototype (WARP). The Food Technology CSC solicitation was released.

During FY 1999, awards will be made for a new biology-inspired NRA, which includes machine-human interface research. ALS milestones include: continued focused applied research efforts at ARC and KSC; and completion of the ALS Systems Integration Test Bed- facility construction at JSC, including construction and installation of the interconnecting tunnel and airlock for the four chambers and ground support utilities. SHF milestones include the initiation of research projects ranging from communications interactions within the control center to expanded modeling of joints and strength for human application to EVA. Data from the inflight restraint study will be analyzed and results published. AEMC milestones include the successful flight of the Electronic Nose Flight Experiment on STS-95 and the Space Shuttle flight test of a miniature quadrapole mass spectrometer and completion of Phase II for the WARP. The Environmental System CSC solicitation will be released and the Food Technology CSC will be awarded and initiated.

In FY 2000, ALS milestones include completion of the ALS Systems Integration Test Bed design including the major systems buildup for a 30-day "precursor" habitat. SHF focus will be on the performance capabilities of the human with specific emphasis on habitability, on-orbit training, information and design issues and human-system interactions. AEMC will continue to focus on the pursuit of innovative sensor technologies in ground-based technology research and in-flight payload development. The Environmental Systems CSC will be awarded and initiated.

BASIS OF FY 2000 FUNDING REQUIREMENT

BIOMEDICAL RESEARCH AND COUNTERMEASURES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Biomedical Research and Countermeasures (BR&C)	41,542	59,700	53,000

GOALS

The goals of BR&C are to: (1) reduce risk to crew health from space radiation; (2) reduce risk of acute and chronic health problems, and of psychological and behavioral problems, that increase probability of crew mortality and/or morbidity, decrease crew productivity in flight, or prevent crew resumption of a full, healthy life on Earth; and (3) transfer biomedical knowledge and technology gained through research on the ground and in space to the Earth-based medical community.

STRATEGY FOR ACHIEVING GOALS

BR&C includes research on physiology and behavior, biomedical countermeasures, operational and clinical problems, environmental health, and radiation health. BR&C seeks to characterize and determine the mechanisms of physiological changes in weightlessness, including those that threaten to limit the duration of human space missions. It also develops methods that allow humans to live and work in microgravity, optimize crew safety, well being and performance, and minimize the deleterious effects of returning to earth's gravity after space flight. It attempts to specify, measure, and control spacecraft environments and develop standards and countermeasures, where necessary, to optimize crew health, safety, and productivity. It develops monitoring techniques, procedures, and standards for extended missions. It also seeks to establish the scientific basis for protecting humans engaged in the development and exploration of space from radiation hazards.

Center Support

JSC is the Lead Center for BR&C. As Lead Center, JSC coordinates ARC and KSC supporting center activities. JSC also manages the significant ground-based grant activities and all flight experiment activities focused on human research. ARC supports biomedical research investigations and plays the primary life sciences role in the development of biomedical flight experiments that require non-human subjects. KSC provides pre- and post-flight support for BR&C flight experiments. The NSBRI, a joint cooperative agreement between a seven university consortium led by Baylor College of Medicine and JSC, leads a national effort to accomplish integrated, critical path research in biomedical research and countermeasures development.

MEASURES OF PERFORMANCE

The actual data reported is based on interim information available as of mid-December 1998. Complete 1998 data will be available in February 1999 with publication of the 1998 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Number Principal Investigations	192	153	163	157	185
Number of Co-Investigators Supported	460	275	398	277	325
Number of Publications	290	280	249	285	335

ACCOMPLISHMENTS AND PLANS

During FY 1998. the transition of program management responsibility. including grants administration, from HQs to JSC continued. In flight research, 26 experiments comprised the complex. dedicated Neurolab mission (STS-90) that flew on schedule in April 1998. Among firsts. the autonomic nervous system team recorded human sympathetic nerve activity in flight, which may lead to a new understanding of mechanisms underlying orthostatic hypotension. Genomic instability research was jointly funded by the NASA space radiation health project and the National Cancer Institute. An Implementation Memorandum with the Department of Energy established NASA's commitment to support the Booster Applications Facility (BAF) at Brookhaven National Laboratory. This facility is essential for simulating heavy ion space radiation. BR&C completed its research activities on NASA-Mir with the return of the seventh astronaut participant in this project. The project included 44 human life sciences investigations.

During FY 1999, BR&C's 23 flight investigations planned for early ISS will begin a rapid development phase to enable their flight in the FY 1999-2001 time frame. Also, experiments exploring physiological changes associated with aging were successfully flown on the SI'S-95 Research Module mission in collaboration with the National Institute on Aging. Experiments will be selected for the STS- 107 Research Module mission. An integrated Critical Path Research Plan will be developed to outline a biomedical risk-based mitigation strategy for assuring future successful long-duration human space flights. In FY 1999 NASA will utilize the $6.5M budget increase to fund several space radiation research activities. These activities will expand efforts in cooperation with Loma Linda University and Brookhaven National Laboratory that will take advantage of the Loma Linda proton beam facility and the Brookhaven heavy ion accelerators to simulate space radiation. NSBRI will continue its work on the development of countermeasures. with increased emphasis on collaboration and interaction across physiological disciplines and across institutions.

During FY 2000, BR&C will continue to integrate and augment its efforts towards validating countermeasures produced by the NSBRI, and ground-based research and technology programs. The flight program will increase its utilization of the ISS with the launch of the HRF rack, which enables initiation of complex human physiologic studies on board ISS. In addition, approximately eight BR&C payloads will be carried out on the STS- 107 Research Mission. Final preparations will be made for an experiment to characterize the radiation environment on the surface of Mars as part of the Mars Surveyor program 2001 Orbiter and Lander missions. Space radiation health will intensify international collaboration in the use of high energy heavy ion facilities, cooperation with Loma Linda University, and expand the research community involving, where appropriate, joint support of research efforts by NASA, NIH and other agencies of the Federal government.

BASIS OF FY 2000 FUNDING REQUIREMENT

GRAVITATIONAL BIOLOGY AND ECOLOGY

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Gravitational Biology and Ecology (GB&E)	28,870	40,900	38,600

GOALS

The goals of GB&E are: (1) determine and elucidate the effects of gravity on, and the gravity response of, cellular structures, the genome, cells, physiological systems, organisms and their development, ecosystems, and biological evolution; (2) apply knowledge to support human space flight via countermeasures and bioregenerative life support systems, and further exploration of space via terraforming technologies; and (3) transfer biological knowledge and technology gained through research on the ground and in space to the Earth-based medical and scientific communities.

STRATEGY FOR ACHIEVING GOALS

GB&E seeks to improve understanding of the role of gravity in biological processes by using a variety of gravitational environments as research tools or by determining the combined effects of gravity and other environmental factors on biological systems. It emphasizes research in cell and molecular biology, evolutionary and developmental biology, and organismal and comparative biology. Its research includes plants, animals, or other organisms as subjects, as well as cell or tissue cultures. The disciplines supported are Physical Interactions, Cellular and Molecular Biology, Developmental Biology, Plant and Comparative Biology, Global Monitoring and Disease Prediction, Gravitational Ecology (planned), and Evolutionary Biology (planned). GB&E is also the Lead Center for Life Sciences Outreach.

Center Support

ARC is the Lead Center for GB&E. GB&E also draws upon other centers on occasion to administer tasks or for other unique expertise. KSC provides pre- and post-flight support for GB&E flight experiments. A key collaborative venture between GB&E and the National Institutes of Allergy and Infections Diseases is the use of remote sensing technologies for the prediction and control of global vector-borne human disease such as malaria.

MEASURES OF PERFORMANCE

The actual data reported is based on interim information available as of mid-December 1998. Complete 1998 data will be available in February 1999 with publication of the 1998 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Number of Principal Investigations	88	127	92	153	157
Number of Co-Investigators Supported	90	138	100	175	180
Number of Publications	170	248	190	300	310

ACCOMPLISHMENTS AND PLANS

During FY 1998, the transition of program management responsibility, including grants administration, from HQs to ARC was completed. In flight research, experiments were flown on the Neurolab mission. Preliminary results from Neurolab (STS-90) demonstrated that exposure to microgravity affected early processes in the cellular development of the nervous system. The technical content of GB&E was evaluated and redirected as part of a major restructuring and re-prioritization of goals consistent with the HEDS strategic planning priorities. Ground based research new starts were limited due to funding constraints. Work continued in support of improved global health through the use of space technology. Twelve investigators from a variety of countries including the U.S. came to ARC for a period of several months each to receive training in the application of remote sensing. The goal was to prepare them to use this technology to address human health needs in their respective countries. Investigations were selected to be conducted on the ISS. Proposals for a new Consortium/Center for Research in Evolutionary Biology were solicited and are under evaluation. A collaborative working relationship with the Astrobiology Institute is being developed.

During FY 1999, efforts to restructure and expand the scope of GB&E consistent with the NASA and HEDS strategic plans will continue. New research proposals emphasizing biology-inspired technologies will be awarded. An integrated research activity in evolutionary biology will be developed and investigations selected and awarded. Data from Neurolab flight experiments to define the time course of adaptations in the balance system to alter gravitational environments and to compare the responses of at least three different biological models to understand the influence of gravity on the normal development of the nervous system will be analyzed. Data from research carried out on MIR will be analyzed to achieve a one crew year "jump start" for ISS fundamental biology. Experiments will be selected for the STS-107 Research Module mission. The experiment candidates include research on plants, aquatic specimens, cells, and mice.

During FY 2000, GB&E flight experiments will provide information on the effects of exposure to microgravity on plant growth and development, and information to determine the effects of gravity on plant photosynthesis and respiration. GB&E will commence research in evolutionary biology with participation of at least 5 research institutions. Flight research on the effects of microgravity on avian development will be carried out. Research proposals on Biological Inspired Technologies will be solicited. Fundamental biology research will be conducted on the STS-107 Research Module mission.

BASIS OF FY 2000 FUNDING REQUIREMENT

MICROGRAVITY RESEARCH

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Microgravity Research (MR)	100,400	113,700	111,400

GOALS

MR seeks to use the microgravity environment of space as a tool to advance knowledge, to use space as a laboratory, to explore the nature of physical phenomena, contributing to progress in science and technology on Earth; and to study the role of gravity in technological processes, building a scientific foundation for understanding the consequences of gravitational environments beyond Earth's boundaries.

STRATEGY FOR ACHIEVING GOALS

The MR strategy for achieving the goals includes sustaining leading-edge research focused in the areas of biotechnology, combustion science, fluid physics, fundamental physics, and materials science that effectively engages the national research community; fostering an interdisciplinary community to promote synergy, creativity and value in carrying out the research. Enable research through the development of an appropriate infrastructure of ground-based facilities, diagnostic capabilities and flight facilities/opportunities and promoting the use of smaller apparatus. Promote the exchange of scientific knowledge and technological advances among academic, governmental and industrial communities and disseminating the results to the general public and to educational institutions. Raising the awareness of the microgravity research community regarding the long-term direction of the HEDS enterprise, and discuss with the community the role of microgravity research in support to agency objectives.

Center Support

MSFC is the Lead Center for MR, drawing upon GRC, JSC, and JPL to administer tasks or for other unique expertise. MSFC provides pre- and post-flight support for MR flight experiments. The National Center for Microgravity Research on Fluids and Combustion, a joint cooperative agreement between the Universities Space Research Association, Case Western Reserve University and GRC, leads a national effort to increase both the number and quality of researchers and to accomplish integrated, critical path research in microgravity fluids and combustion sciences. A new National Center for Microgravity Research in Biotechnology and Materials Science will be formed in FY 2000.

MEASURES OF PERFORMANCE

The actual data reported is based on interim information available as of mid-December 1998. Complete 1998 data will be available in February 1999 with publication of the 1998 OLMSA Life Sciences and MR Program Tasks and Bibliographies annual report.

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Number of Principal Investigations	349	465	344	451	543
Number of Co-Investigators Supported	395	446	395	505	600
Number of Publications	1370	1880	1420	1775	2140

ACCOMPLISHMENTS AND PLANS

During FY 1998, MR conducted broad, productive Earth-based and space-based research. The Fourth United States Microgravity Payload (USMP-4) mission was successfully completed, the final flight of this successful series. Initial results included observation of new physical behavior when matter is confined to only two dimensions during the Confined Helium Experiment (CHeX), which investigated the nature of boundary effects on materials and their properties by examining the superfluid transition of helium. Two studies focused on the process of crystal growth of advanced, "solid-solution" semiconductor materials that serve as infrared detectors. The growth speed and crystal size of a material that serves as a model for industrially useful metals was measured for the first time, without the effects of gravity. Joint American-French research provided the first evidence of certain important crystal growth driving forces in engineering materials whose properties depend strongly on crystallographic direction. Research using NASA's bioreactor was also carried out on the Neurolab mission (STS-90) providing the first information on how microgravity affects the functions of genes from cells. An experiment carried out on STS-89 provided basic understanding of the phenomena that contribute to earthquakes and grain silo explosions. The Solid Surface Combustion Experiment completed its ten-flight long investigation into the laws of burning of solids on STS-91.

MR's activities in the NASA/Mir Science Program were successfully completed. The Mir Glovebox Facility and the Space Acceleration Measurement System (SAMS) were both returned to Earth for inspection after years of deployment and thousand of hours of research use in the Priroda Module, a dress rehearsal for equipment use on the ISS. Research operations in Protein Crystal Growth using the Gaseous Nitrogen Dewar was completed, demonstrating the ability of the new technique to screen a large number of crystal growth conditions at lower cost than on prior shuttle missions. Crystals grown on Mir of Human Immunodeficiency Virus protease inhibitors had better resolution and quality than those grown on Earth, and may assist ground based researchers in defining the structure of the protein(s) which may be important in fighting the AIDS virus. Perhaps even more significant is the large number of trials conducted on Mir growing "model" proteins, to uncover nature's laws that govern the growth of these crystals both on Earth and in space. Analysis of this data will require two years, but may lead to improved crystal growth techniques on Earth as well as more successful growth on the ISS of important proteins related to major diseases.

The first three MR flight investigations for ISS were authorized for full development: Physics of Colloids in Space (PCS), Dynamically Controlled Protein Crystal Growth (DCPCG) and Observable Protein Crystal Growth (OPCGA). The Space Station Furnace Facility was redefined into a more versatile Materials Science Research Facility (MSRF), guided by review of the National Research Councils' National Materials Advisory Board. Redesign of the ISS Fluids and Combustion Facility (FCF) concept was completed as a series of stand-alone 'integrated racks' to accommodate early science within the stretched launch schedule and lowered microgravity research ISS budgets. Full scale mock-ups of the FCF integrated rack concepts were completed and displayed to the user.

Focus on NASA/NIH cooperative activities to transfer the results of MR to the biomedical community continues. Researchers at the NASA/NIH Center for Three-Dimensional Tissue Culture have already produced the first in vitro tissue system which permits the study of HIV pathogeneses inside human lymphoid tissue. In addition, there are currently fifteen ongoing projects at the center addressing a spectrum of biomedical research issues that the NIH identified as having the potential to benefit from the NASA tissue culture technology. To further accelerate NASA bioreactor research on the culturing of human tissues, NASA has renewed this important initiative with the NIH for four additional years. A Foundation for Transplant Research was instituted with VivoRx Corporation using the NASA Bioreactor technology. The Food and Drug Administration worked with NASA to apply microgravity technology on earth to the early detection of cataracts. New, high energy and low cost X-ray technology for space- and Earth-based crystallography was under development by NASA, NIH and industry as a cooperative effort.

In FY 1999, MR will focus on utilization of earth-based facilities for short duration microgravity, preparation of future flight research, two investigations using suborbital rockets and a number of research activities on the STS-107 Research Mission. Research needed to generate low-gravity technology required to advance human exploration of the solar system will be conducted. Definitive conclusion and publication of the results of the Mir Missions will be completed, in particular to provide a three-year advance in techniques for protein crystallization and cell culture research in space. Combustion science, materials science and fluid physics results from the First Microgravity Science Laboratory mission flown in FY 1997 will be published, providing new information on soot formation, the relation of molten material mixing on final solid structure, and colloid crystallization.

In FY 2000, MR will focus on utilization of earth-based facilities for short duration microgravity, preparation of future flight research, two investigations using suborbital rockets and focused research activities on the STS-107 Research Mission. Initial research operations using the ISS will take place. Research needed to generate low-gravity technology required to advance human exploration of the solar system will be expanded. New research projects will be selected in materials science and fluid physics in preparation for the deployment of major and sophisticated research apparatus of those fields on the ISS in FY 2001 and FY 2002. The investigations for early ISS delivered in FY 1999 will be deployed and operated. The ISS FCF and MSRF will complete Critical Design Reviews. Assembly and checkout of the Combustion Integrated Rack and implementation of the detailed design of the Fluids Integrated Rack will be completed.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE PRODUCT DEVELOPMENT

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Space Product Development (SPD)	12,900	15,400	14,400

GOALS

The goals of SPD are: (1) to facilitate the use of space for commercial products and services; and (2) to use the unique attributes of space to conduct industry driven research in which materials or knowledge developed in space can be used on Earth for the development or improvement of a commercial product or service.

STRATEGY FOR ACHIEVING GOALS

SPD includes support to the operation of the NASA CSCs, commercial flight research hardware for Shuttle and parabolic aircraft flights, and a limited number of NASA projects in support of commercial objectives. It is a partnership of industry, universities, and local, state, and other federal agencies engaged in commercial space research. SPD encompasses a broad range of NASA efforts to encourage industry participation and investment in space. Commercial space research has the potential to create new or improved products, create jobs, give U.S. industry competitive advantages and improve the quality of life on Earth.

In the 1st Quarter of FY 1999, NASA released the draft Human Exploration and Development of Space (HEDS) Enterprise Commercial Development Plan for the International Space Station. The plan will be refined and begin initial steps towards implementation later in FY 1999.

Center Support

The SPD program is managed for NASA by the MR Program Office at the MSFC. The SPD program is primarily implemented through CSCs. Each CSC is a non-profit consortium of commercial, academic, and/or government entities. The CSCs follow business leads and commitments to pursue product-oriented research in three major disciplines: materials research and development, biotechnology, and agriculture. NASA's role in this partnership is to provide leadership and direction for the integrated program and to provide the flight opportunities that are essential to the success of these efforts.

The CSCs have a unique role in assisting private businesses to conduct space research. They demonstrate to industry the values of space research, and they provide expertise essential to the conduct of successful research in space. CSCs furnish an infrastructure that provides a cost-effective and efficient way for industries to conduct research in space. The CSCs initiate industry involvement: first, by identifying and investigating research areas of industry-led commercial promise; and, second, by assessing markets for these potential research opportunities. The businesses support the research effort with resources including cash and in-kind such as, technical expertise, research materials, personnel, ground facilities, and research hardware.

MEASURES OF PERFORMANCE

The measures of performance for SPD program capture the number of university and industry affiliates that are working with NASA in the commercialization of space and the amount of funding leveraged from non-NASA sources by the CSCs.

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Industry Affiliates	136	136	198	145	162
University Affiliates	58	58	50	68	80
Payloads Flown	4	4	14	11	12
Non-NASA $M Leveraged	$49.3M	$49.3M	$53.6M	$55.0M	$60.0M

ACCOMPLISHMENTS AND PLANS

During FY 1998, many products enabled by SPD have successfully progressed through various stages of development. Examples include: a new treatment for influenza, developed with the aid of information from space-grown crystals, continues to advance through the drug development and approval process. BioCryst Incorporated, a commercial partner of the Center for Macromolecular Crystallography, has teamed with Johnson and Johnson to develop and market this drug worldwide. Preliminary testing shows the drug to be effective against influenza A and B viruses, and human clinical trials are getting underway.

Proleukin, developed by Chiron Corporation through partnership with BioServe Space Technologies, has been approved by the FDA for use in treatment of bladder cancer and metastatic melanoma. In addition, it is being used in human clinical trials to test its effectiveness as an adjunct treatment for AIDS.

Myotrophin has been submitted by Chiron as a New Drug Application to the FDA for use as a treatment of a neural degenerative disease. The company is also evaluating it as a potential treatment for skeletal disorders, since flight research has demonstrated its effectiveness in preventing the reduction of bone formation that results from space flight.

Chagas disease, a serious health problem in Central and South America is receiving heightened interest through work done by the Center for Macromolecular Crystallography. New studies made possible by the high-quality protein crystals grown on the Shuttle have resulted in significant advances.

Ford Motor Company has used materials data supplied by the Solidification Design Center, a CSC, to design new, high-quality sand molding processes for creating precision automotive parts. This type of work is also being done for ALCOA and Howmet Corporation to help them cast parts that are more reliable with lower production costs.

Brush Wellman Incorporated, successfully produced the world's largest aluminum-beryllium casting with the assistance of ground-based casting data and computational models developed by the Solidification Design Center.

A special optical detector developed by the Space Vacuum Epitaxy Center, a CSC, may offer the hope of sight to people with a variety of eye problems. The detector is designed to be implanted on the back wall of the eye to replace natural sensors damaged by disease or accident. It converts light into electrical signals in much the same way as rods and cones do in a healthy eye, and the impulses are then picked up by the optical nerve. Preliminary testing has been successful and efforts at commercial development are underway.

During FY 1999, SPD will continue near term, precursor research in biotechnology, agriculture and materials processing as well as preparation for flight for commercial investigations planned for the ISS. Research payloads under development include Commercial Instrumentation Technology Association (ITA) Biomedical Experiments, Commercial Protein Crystal Growth and the Microencapsulation Processing System. Materials processing experiments under development range from bone replacement materials to optical fibers. Payloads in development for subsequent ISS flight opportunities include Vulcan hardware, which will be used to collect thermophysical property data of numerous advanced materials that are of interest to industry. The Space Experiments Facility will be flown as part of the first Materials Science Research Rack, collaboration with MR. SPD plans to establish dual-use centers in Food Technology and Environmental Systems, each with a minimum of five affiliates and with contributions at least equal to NASA's contribution. OLMSA will also seek to establish a policy and approach for SPD to sponsor humanitarian international cooperation projects in pharmaceuticals, biotechnology, and medical informatics to contribute to improved health.

During FY 2000, CSCs will continue to be focused on utilization of the ISS for their industry partners, developing and preparing research hardware for flight, and collecting and analyzing results for incorporation into product development activities. A number of commercial research projects using existing flight hardware will be available for flight opportunities. For example, two of the 12 commercial research payloads planned for the STS-107 Research Module mission, involve a project to improve fire suppression using water mists, and a project to produce optical fibers of unprecedented purity. Several product development efforts should reach commercial transition, particularly in the biomedical research area that has used the Commercial Generic Bioprocessing Apparatus and the Commercial Protein Crystal Growth carriers to conduct commercial microgravity research. The Yale informatics center will establish its terrestrial test sites for medical informatics and sensor technologies and will establish a telemedicine hub in Western Europe. SPD will also review and make recommendations on the need for additional CSCs, e.g. for textiles, polymers, photonics, consistent with review group recommendations.

BASIS OF FY 2000 FUNDING REQUIREMENT

OCCUPATIONAL HEALTH RESEARCH

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Occupational Health Research (OHR)	830	900	1,100

GOALS

The goals of OHR are focused on improving NASA's OHR program effectiveness and efficiency through the following programmatic improvements: program standardization and automation; increased inter-center communication; International Organization for Standardization (ISO) compatible programs assessment; technical support center augmentation; and a training program development.

STRATEGY FOR ACHIEVING GOALS

OHR establishes policies and manages implementation of NASA-wide occupational and environmental health activities and services. The OHR function consists of several well-defined constituent activities including Occupational Medicine, Industrial Hygiene, Radiation Health, Physical Fitness, Employee Assistance Programs, Workers' Compensation, Nutrition and Food Safety, and Wellness and Health Education. Collectively, these constituent activities assure the well being and productivity of the NASA work force. OHR has the primary responsibility for the control and elimination of harmful exposures of NASA employees to toxic chemicals and hazardous physical agents, for the prevention of occupational disease and injury, and the promotion of optimal health, performance and productivity. KSC is the Lead Center for OHR.

MEASURES OF PERFORMANCE

Agency Workers' Compensation Rates Plan: 1st Quarter FY 1999	Reduce NASA charge-back billing through the acquisition and implementation of a new case tracking data management system
Early Medical Diagnosis Plan: 4th Qtr, FY 98	Utilization rates of key preventive services such as medical surveillance, employee assistance programs, and fitness centers are indication of positive risk factor interventions aimed at keeping the work-force healthy and productive.

ACCOMPLISHMENTS AND PLANS

During FY 1998, the Occupational Health and Safety Executive Board with a subcommittee on Health, Environmental Management, and Safety held initial meetings to advise on Agency policy in occupational health. Work began on developing web-based training modules on federally mandated occupational health activities. Interagency OHR service agreements were put into place. Evaluation of occupational health management systems for Agency wide use began. Benchmarking of Federal agencies and select Fortune 500 companies' OHR activities was initiated. Agency policy development began for coping with downsizing and other workplace stresses. Department of Veterans Affairs computerized management system for Workers' Compensation claims was instituted. A series of International Public Health Policy seminars, providing professional continuing education credit was conducted comparing health policies and research agendas of seven nations to those of the United States.

During FY 1999, OHR will conduct a series of continuing education ViTS seminars on the Bioethics of practice and broadcast them to the Institute of Biomedical Problems in Moscow, the Commercial Center for Medical Informatics and Technology at Yale, other select academic institutions within the U.S., and all NASA centers. The benchmarking of OHR activities will be expanded to include outstanding private industry organizations, selected through the American Productivity and Quality Control (APQC). A streamlined process verification of Center OHR activities will be implemented. Formal collaborations with the CDC and the American Heart Association will be investigated for potential collaborative use of the HERO database and development of an outcomes-based health Risk Appraisal instrument. An Occupational Health technical support center will be established. An on-line support network of Agency resources on critical occupational health issues will be created. Development of web site training modules for Employee Assistance topics will begin. OHR will also begin evaluation of the possibilities for third party reimbursement of select medical services for partial cost recovery based on data from a pilot study initiated at GRC.

During FY 2000, OHR will evaluate the consolidated contract support for Center OH activities and services. The process to fully automate a health information management system will begin. The Center Process verification program methodology for OHR will be evaluated for effectiveness. Benchmarking results from the APQC will be evaluated for implementation to Center OHR activities. Pursuit of collaborative efforts with the CDC will continue.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE MEDICINE RESEARCH

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Space Medicine Research (SMR)	6,670	6,700	7,100

GOALS

The goals of SMR are (1) to ensure the health, safety, and performance of space flight crew members on all U.S. missions: Space Shuttle, the ISS, and the exploration missions; and (2) define and establish the requirements for clinical care and medical research.

STRATEGY FOR ACHIEVING GOALS

SMR has established five inter-related elements: mission support for the Shuttle and ISS Program, astronaut health care, epidemiology (longitudinal studies of astronaut health), Space Medical Monitoring and Countermeasures (SMMaC), and Clinical Care Capability Development (CCCDP). SMR develops the policies and requirements to maintain and provide medical support to optimize the health, safety and productivity of our astronauts in space. It also develops technologies and applications, including telemedicine. SMR provides guidance and oversight of the medical operational support for human space flight and astronaut health care. SMR's scope ranges from the development of astronaut health policies, standards, and requirements for medical operations and medical research as well as the implementation of these requirements through operational medical support for all human space flight programs.

Center Support

JSC is the Lead Center for SMR. JSC manages telemedicine efforts in support of medical operations activities for the Human Space Flight (HSF) Program. Wright State University School of Medicine, Yale University School of Medicine, and the University of Texas Medical Branch at Galveston are the major participating academic institutions.

MEASURES OF PERFORMANCE

Crew Health Care System		Begin on orbit assembly and setup of CHeCS. Develop protocols and test the capability of the CHeCS as integrated into the ISS.
Plan:	2nd Qtr 00	
Actual:	3rd Qtr 99	

ACCOMPLISHMENTS AND PLANS

During FY1998, SMR successfully provided guidance to the operational medicine community at JSC for operational medical support for Shuttle and for NASA-Mir missions, which came to a successful conclusion in the spring. SMMaC completed implementation of Medical Evaluation Requirements (MERs) on NASA-Mir missions that provided new medical and environmental information about long-duration space flight that will help ensure the health and safety of ISS crewmembers. CCCDP was initiated to evaluate and refine space flight medical requirements and procedures and to identify and develop technologies required for the delivery of inflight crew health care. CCCDP activities included successful flight evaluation of the Telemedicine Instrumentation Pack (TIP) on STS-89 and the identification of technology development areas that will be key to delivery of effective medical care during long duration space flight. The Agency Strategic Plan for Telemedicine was implemented through partnerships with the NASA Centers and the CSC for Medical Informatics and Technology (MITA) at Yale University. Transition of management responsibilities to the Yale CSC began for the Internet-based telemedicine test bed, Spacebridge to Russia, as well as interaction with the Space Biomedical Center for Research and Training. Epidemiology continued to examine the incidence of acute and chronic morbidity and mortality among astronauts to better define the medical risks associated with space flight.

During FY1999, SMR will continue to support the needs of the operational medicine community for Shuttle missions and will begin operational medicine support for the ISS with a team dedicated to medical support of the First Increment Crew. ISS CHeCS components will be deployed early in the ISS assembly sequence to provide on-orbit medical, environmental, and countermeasure capabilities for all ISS crewmembers. Medical and environmental information gained from SMMaC will foster refinements in Shuttle and ISS medical systems, protocols, and procedures. CCCDP will continue to support the ongoing evolution of space medicine requirements, procedures, and technologies. Mature telemedicine activities, including the Internet-based telemedicine test bed, Telecollaboration On Line Database (TOLD) (formerly called Spacebridge to Russia) and the Space Biomedical Center for Research and Training will be conducted through the CSC MITA at Yale University. Plans will be developed to augment ISS CHeCS with telemedicine capabilities and other new and emerging medical and environmental technologies. Epidemiology will continue to evaluate the growing body of astronaut health data to better define the medical risks associated with space flight.

During FY 2000, SMR will continue to support the needs of the operational medicine community for Shuttle and ISS missions. Additional ISS CHeCS components will be utilized to provide on-orbit medical, environmental, and countermeasure capabilities for all ISS crew members. In-flight Shuttle and ISS medical capabilities will be augmented with new flight-proven technologies. Medical and environmental information gained from SMMaC will be utilized to refine medical flight system requirements, protocols, and procedures. CCCDP will continue to provide impetus for the evolution of space medicine requirements, procedures, and technologies. Epidemiology will continue to better define the human medical risks associated with space flight and the effectiveness of operational countermeasures in dealing with these risks.

BASIS OF FY 2000 FUNDING REQUIREMENT

MISSION INTEGRATION

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Mission Integration (MI)	4,900	1,700	1,400

GOALS

The goals of MI are: (1) provide physical, analytical, and operations integration support to achieve NASA mission objectives for the science and technology communities; and (2) ensure integrated scientific, technological, and commercial user advocacy and coordination of requirements for the next generation of space laboratories, the ISS. These activities include the integration, coordination and policy planning and analysis for International research activities within OLMSA.

STRATEGY FOR ACHIEVING GOALS

In order to meet the function goals and objectives, MI performs the space-based research utilization planning of all OLMSA Space Shuttle and ISS payloads. In addition, through this function, MI carries out systems engineering efforts to develop and evaluate strategies and processes for satisfying current and future research mission objectives. These tasks not only address the current human based space flight platform mission integration processes, but, based on this knowledge base, they define and support new effective and efficient processes and tools for carrying out integrated research advocacy, requirements coordination, mission planning and operations for future space platforms. In particular, the program is investigating ways to apply the engineering and operations lessons learned in the Spacelab program and the NASA/MIR Research Program (NMRP) to the ISS program to achieve greater efficiencies.

Center Support

HQs is the Lead Center for MI. The principal NASA Centers, which conduct activities in support of MI, are JSC, KSC, and MSFC. MSFC provided the analytical integration and operations level project management support for the USMP-4, flown in the first quarter of FY 1998. KSC provided the physical hardware science payload integration project management support for the NASA science payloads USMP-4 flights. In FY 1998, JSC provided the analytical integration and operations level project management support for two NMRP missions (NASA/Mir 8 and NASA/Mir 9), the Neurolab mission and the first of two DOE-sponsored Alpha Magnetic Spectrometer (AMS) flights. KSC provided the physical hardware science payload integration project management support for Neurolab. SpaceHab will provide payload management and integration for research payloads on the STS-95 Research Module mission in FY 1999, and the STS 107 Research Module mission in FY 2001.

MEASURES OF PERFORMANCE

The most significant measure of MI's performance is the provision of an integrated system that ensures successful accomplishment of the science payload objectives on Space Shuttle missions that carry OLMSA sponsored research. Although not directly responsible for the success of a particular experiment, MI is responsible for ensuring that all necessary planning and integration of the collected set of instruments have been comprehensively completed and fully coordinated so that the experimental hardware in concert with flight crew performance and ground control direction have the opportunity to conduct the planned science activities. Science payload objectives vary considerably depending upon the type of mission supported (module missions, pallet/MPESS missions or Space Shuttle Middecks) and the type of scientific investigations performed (microgravity, life sciences, Earth and stellar observations). Depending upon the type of payload, performance is measured in terms of the number of primary missions and the number of Middeck missions successfully flown as scheduled and the successful accomplishment of the science payload objectives:

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Spacelab/SpaceHab/Pallet/Shuttle Attached Missions	3	3	1	1	--
Mir Missions	2	2	--	--	--
Middecks/Small Payloads	6	6	4	4	--

ACCOMPLISHMENTS AND PLANS

In FY 1998, MI provided mission management support to the launch of the USMP-4 and Neurolab missions in addition to two flights to Mir, one of which also flew the first flight of the AMS. Systems engineering efforts continued to support methodologies for advocacy and coordination of U.S. research requirements and implementation of processes and tools for mission planning for U.S. payloads on the ISS. Space Station planning and integration efforts intensified concomitant with the First Element Launch of the ISS. Spacelab-related activities were largely completed in FY 1998, as the Spacelab modules flew for the last time in April 1998.

During FY 1999, MI will provide support for one Shuttle mission: the STS-95 Research Module mission. In addition, MI support will be provided for the second in the series of two research missions (STS-107) to provide a transition between the completed Shuttle missions and onset of significant research capability on-board the ISS. These missions are also intended to be pathfinders for future commercial involvement in carrying out orbital research, and will be implemented through commercially provided carriers and carrier integration services. . In addition, the costs for the mission chargeable to NASA will be supported with a combination of ISS research funding and OLMSA funding.

NASA is developing a plan for a "standby research mission", involving both new and reflown scientific research, which could be inserted into the shuttle manifest if and when a schedule anomaly occurs. This plan is due to be submitted to the Senate in February 1999.

During FY 2000, MI will continue support for the second DOE sponsored AMS mission planned for the ISS. Space Shuttle "pathfinder" research missions will provide continuing space access to the science and commercial programs until a substantive research capability is available on the ISS in 2002. Support will continue for the STS-107 Research Module mission, scheduled to fly in FY 2001, and fly microgravity, life sciences, and commercial research payloads. This flight opportunity is independent of the ISS Research Program and has been advertised to the ISS partners as opportunities to allow them to begin ISS-type flight experience earlier than planned in the ISS Program. The STS-107 mission will include a double module for accommodating research hardware and will be provided by SpaceHab, Inc. To offset costs, SpaceHab Inc. has been allocated some of the carrier capability to market to non-NASA customers, including ISS partners who wish to take advantage of this research opportunity before they have access to ISS utilization. In return, the costs for the mission chargeable to NASA for its payloads would be offset. This strategy was tested successfully on the first flight, STS-95 and was considered to be a "pathfinder" in terms of the space flight commercialization process.

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF EARTH SCIENCE **EARTH SCIENCE**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Earth Observing System	754,500	631,100	663,200	SAT 3-8
Earth Observing System Data Information System	210,100	261,700	231,500	SAT 3-29
Earth Probes	34,900	109,700	138,200	SAT 3-34
Applied research and data analysis	373,400	400,600	420,200	SAT 3-40
Global observations to benefit the environment	5,000	5,000	5,000	SAT 3-62
Launch services	39,400	4,200	---	SAT 3-64
Construction of facilities	---	1,500	1,000	SAT 3-65
Total	1,417,300	1,413,800	1,459,100	

Distribution of Program Amount by Installation

Johnson Space Center	400	---	---
Kennedy Space Center	100,620	92,700	66,900
Marshall Space Flight Center	25,882	18,600	38,300
Stennis Space Center	37,793	40,400	32,700
Ames Research Center	8,560	10,200	13,300
Dryden Flight Research Center	21,456	16,900	19,000
Langley Research Center	39,876	34,900	59,900
Glenn Research Center	7,414	---	---
Goddard Space Flight Center	930,000	928,300	916,000
Jet Propulsion Laboratory	219,337	222,100	251,700
Headquarters	25,962	49,700	61,300
Total	1,417,300	1,413,800	1,459,100

EARTH SCIENCE ENTERPRISE

PROGRAM GOALS

The purpose of NASA's Earth Science Enterprise (ESE) is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. Earth science is pioneering the new interdisciplinary field of research called Earth system science, born of the recognition that the Earth's land surface, oceans, atmosphere, ice sheets and *biota* are both dynamic and highly interactive. It is an area of research with immense benefits to the nation, yielding new knowledge and tools for weather forecasting, agriculture, water resource management, urban and land use planning, and other areas of economic and environmental importance. In concert with other agencies and the global research community, Earth science is providing the scientific foundation needed for the complex policy choices that lie ahead on the road to sustainable development. Earth science has established three broad goals. They are to 1) expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft and *in situ* platforms; 2) disseminate information about the Earth system; and 3) enable productive use of Earth science program science and technology in the public and private sectors. The Earth Science Enterprise has evolved from what was previously called the Mission to Planet Earth Enterprise.

STRATEGY FOR ACHIEVING GOALS

The pursuit of Earth system science would be impractical without the continuous, global observations provided by satellite-borne instruments. Earth science comprises an integrated slate of spacecraft and *in situ* measurement capabilities; data and information management systems to acquire, process, archive and distribute global data sets; and research and analysis projects to convert data into new knowledge of the Earth system. Numerous users in academia, industry, federal, state and local government tap this knowledge to produce products and services essential to achieving sustainable development. Earth science is NASA's contribution to the U. S. Global Change Research Program (USGCRP), an interagency effort to understand the processes and patterns of global change.

The Earth Observing System (EOS), the centerpiece of Earth science, is a program of multiple spacecraft (the AM, PM, Chemistry, Landsat-7, and follow-on and supporting technology) and interdisciplinary science investigations to provide a data set of key parameters needed to understand global climate change. The first EOS satellite launches will begin in 1999. Preceding the EOS were a number of individual satellite and Shuttle-based missions which are helping to reveal basic processes. The Upper Atmosphere Research Satellite (UARS), launched in 1991, collects data on atmospheric chemistry. The Total Ozone Mapping Spectrometer (TOMS) instruments, launched in 1978, 1991, and 1996, measure ozone distribution and depletion. Two TOMS instruments were launched in 1996, one on the Japanese Advanced Earth Observing System (ADEOS) mission and the other on a dedicated U. S. Earth Probe. France and the U. S. collaborated on the Ocean Topography Experiment (TOPEX/Poseidon), launched in 1992, to study ocean topography and circulation. The NASA Scatterometer (NSCAT) mapped ocean winds for one year prior to an on-orbit failure of the Japanese ADEOS-I. In 1997, the Tropical Rainfall Measuring Mission (TRMM) was launched to provide the first-ever measurements of tropical precipitation.

Complementing EOS, under the Earth Probes Program, will be a series of small, rapid development Earth System Science Pathfinder (ESSP) missions to study emerging science questions and to use innovative measurement techniques in support of EOS. The first two ESSP missions, Vegetation Canopy LIDAR (VCL) and Gravity Recovery and Climate Experiment (GRACE) are scheduled for launch in 2000 and 2001, respectively. The next ESSP missions were selected in December 1998. NASA has chosen for development one primary and two alternate small spacecraft missions. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission, co-led by NASA's Langley Research Center and the *Institut Pierre Simon Laplace*, Paris, France will be the next ESSP mission scheduled for launch in 2003. In addition, NASA has chosen two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study at the present time. Based on the study results, NASA may select one of these missions for full development and the other as the alternate mission.

Continuing with the recommendation from the 1997 Earth Science Biennial Review, a process is currently under way to define concepts for science and applications missions in the post-2002 time frame. In developing its measurement/mission strategy, the Earth Science Enterprise desires to reduce the risk to overall program objectives from any single mission failure by developing smaller, less expensive missions and implementing shorter development cycles from mission definition to launch. The objectives are to further develop the scientific measurement strategy implemented in the first series of EOS satellite missions and to take advantage of the latest instrument technologies. Shorter development times will allow more flexible responses to current and evolving scientific priorities and more effective uses of the latest technologies. In accordance with this philosophy, the implementation of each future mission in the Earth Science Enterprise (ESE) flight program will be based on a competitive selection of instrument payloads and implementation options. It is important, under this new approach, that instrument technology developments be conducted largely before the relevant mission payload selection. A science and applications-based flight mission profile is indispensable to guide these pre-mission technology developments.

We have obtained a first round of ideas from the science and applications communities for post-2002 mission concepts and are using them to build a nominal multi-mission profile for Earth observation satellite missions in the 2003-2010 time frame.

The purposes of the multi-mission profile are:

- To guide science and application research investments in preparation of the missions;
- To guide ESE technology investment in preparation of the missions; and
- To constitute the basis for discussion with potential commercial and international partners having missions in that time frame for potential cost sharing, collaboration, and partnerships.

The ESE intends to refresh periodically this nominal mission profile through similar consultations with the Earth system science and applications communities. We do not intend to create a 10-year queue of missions, but to promote a theme or focused area at a time leading to selection of one or two missions in each cycle.

Data from Earth science missions, both current and future, will be captured, processed into useful information, and broadly distributed by the EOS Data Information System (EOSDIS). EOSDIS will ensure that data from these diverse missions remain available in active archives for use by current and future scientists. Since these data are expected to find uses well beyond the Earth science research community, EOSDIS will ultimately be accessible by environmental decision-makers, resource managers, commercial firms, social scientists and the general academic community, educators, state and local government—anyone who wants the information.

Following the recommendation of the National Research Council, NASA is exploring the creation of a federation of Earth science information partners in academia, industry and government to broaden the participation in the creation and distribution of EOSDIS information products. As a federation pilot project, 24 organizations were competitively selected in December 1997 to become Earth Science Information Partners (ESIPs) to develop innovative science and applications products.

The intellectual capital behind Earth science missions, and the key to generating new knowledge from them, is vested in an active program of research and analysis. Over 1,500 scientific research tasks from nearly every U. S. state are funded by the Earth science research and analysis program. Scientists from seventeen other nations, funded by their own countries and collaborating with U. S. researchers, are also part of the Earth science program. These researchers develop Earth system models from Earth science data, conduct laboratory and field experiments, run aircraft campaigns, develop new instruments, and thus expand the frontier of our understanding of our planet. ESE-funded scientists are recognized as world leaders in their fields, as exemplified by the award of the 1995 Nobel Prize in chemistry to the two scientists who investigated the threat of cholorflorocarbons to upper atmospheric ozone. The research and analysis program is also the basis for generation of application pilot programs that enable universities, commercial firms, and state and local governments to turn scientific understanding into economically valuable products and services.

The first Earth Science Research Plan was published in 1996. The plan laid out a strategy for study in five Earth system science areas of maturing scientific understanding and significant societal importance: land-cover and land use changes; short-term climate events, natural hazards research and applications; long-term climate change research; and atmospheric ozone research. The plan also outlines some twenty related areas of research which round out the Earth science contribution to Earth system science.

The challenges of Earth System Science, sustainable development, and mitigation of risks to people, property and the environment from natural disasters, require collaborative efforts among a broad range of national and international partners. As mentioned above, the USGCRP coordinates research among ten U. S. government agencies. NASA is by far the largest partner in the USGCRP, providing the bulk of USGCRP's space-based observational needs. NASA has extensive collaboration with the National Oceanic and Atmospheric Administration (NOAA) on short-term climate event prediction. The ESE is the responsible managing agent in NASA for the development of NOAA's operational environmental satellites. NOAA, NASA, and the Department of Defense (DoD) jointly work to achieve the convergence of civilian and military weather satellite systems. NASA collaborates with the U. S. Geological Survey (USGS) on a range of land surface, solid Earth and hydrology research projects. NASA, NOAA and USGS collaborate in the Landsat-7 program, and NASA, DoD and USGS are working together on a third flight of the Shuttle Radar Laboratory modified to yield a digital terrain map of most of the Earth's surface. NASA participates in the World Climate Research Program, the International Geosphere/Biosphere Program, and the ozone assessments of the World Meteorological Organization.

International cooperation is an essential element in the Earth science program. Earth science addresses global issues and requires international involvement in its implementation and application. Acquiring and analyzing the information necessary to address the science questions is a bigger task than a single nation can undertake. Furthermore, the acceptance and use of the scientific knowledge in policy and resource management decisions around the world require the engagement of the international scientific community. Global data and global participation are needed to devise a global response to environmental change. In addition, integrating our complementary science programs can result in fiscal benefits to the NASA program. For this reason, NASA has sought and nurtured international partnerships spanning science, data and information systems, and flight missions. Most of Earth science's satellite missions have international participation, ranging from simple data sharing agreements to joint missions involving provision of instruments, spacecraft, and launch services. In the past three years over 60 international agreements have been concluded and more than 40 more are pending. In some capacity, Earth science programs involve international partners from over 35 nations, including Argentina, Armenia, Australia, Belgium, Brazil, Canada, Chile, China, Denmark, Egypt, France, Germany, India, Israel, Italy, Japan, Mongolia, Russia, South Africa, Ukraine and others.

This budget enables the ESE to continue its mission to understand the total Earth system and the effects of natural and human-induced changes on the global environment. While our mission, goals and objectives remain unchanged, our implementation approach continues to evolve. We remain guided by key over-arching Earth science questions while we refine the contributing, lower level questions in response to recent science results. We are using these science questions to drive our technology investment decisions. We have begun the process of identifying post-2002 mission concepts based on how much a given concept contributes to answering a specific science question.

This budget reflects a direct relationship between our strategic plan goals and the resources necessary to implement them. All elements of the budget are tied to our 11 strategic plan objectives. Each performance target in our section of the NASA Performance Plan for FY 1999 and for FY 2000 is traceable to one or more budget elements.

Our first priority is to ensure the success of the Landsat-7 and AM-1-1 missions and that a viable data management system is in place to support the data flow from these missions. We must also sustain support for our other flagship EOS PM, Chemistry, Ice, Cloud, and land Elevation Satellite (ICESat) missions, and sustain Earth Science System Pathfinders (ESSPs) at a viable level.

In addition to ensuring a robust science program, this budget initiates a vigorous Advanced Technology program that supports development of key technologies to enable our future science missions. In addition to our baseline technology program that includes NMP, Instrument Incubator and HPCC, an Advanced Technology Initiative will identify and invest in critical instrument, spacecraft and information system technologies.

The ESE will lead the way in the development of highly capable, remote and *in situ* instruments and the information system technologies needed to support coupled Earth system models. Together they will enable affordable investigation and broad understanding of the global Earth system. The ESE will emphasize the development of information system architectures to increase the number of users of Enterprise information from hundreds to tens of thousands, with the goal of providing easy access to global information for science, education and applications. Finally, ESE will work in partnership with industry and operational organizations to develop the capabilities and infrastructure to facilitate the transition of sustained measurements and information dissemination to commercial enterprises.

ESE's technology strategy seeks to leverage the entire range of technology development programs offering benefits in cost, performance and timeliness of future Earth science process and monitoring campaigns. ESE's strategy is to establish strong links to other government programs in order to maximize mutual benefit to use open competitions for ESE-sponsored technology programs to attract the best ideas and capabilities from the broad technology community, including industry and academia.

Technology efforts will be made in the following areas:

- Advanced instrument and measurement technologies for new and/or lower cost scientific investigations.
- Cutting-edge technologies, processes, techniques and engineering capabilities that reduce development and operations costs and that support rapid implementation of productive, economical, and timely missions;
- Advanced end-to-end mission information system technologies, technologies effecting the data flow originating at the instrument detector through data archival, for collecting and disseminating information about the Earth system and enabling the productive use of Enterprise science and technology in the public and private sectors.

From FY 2000 on, ESE increases emphasis on a viable Applications, Commercial and Education program that bridges our focused research R&A and mission science investments with the Commercial Remote Sensing Program towards addressing key environmental problems of societal relevance.

The EOS AM-1 will be launched in 1999. This mission will provide key measurements that will significantly contribute to our understanding of the total Earth system. The AM-1 instrument complement will obtain information about the physical and radiative properties of clouds, air-land and air-sea exchanges of energy, carbon, and water, measurements of trace gases, and volcanology.

Landsat-7 is also scheduled for launch in 1999. Landsat-7 will carry a single instrument, the Enhanced Thematic Mapper Plus (ETM+), which will make high spatial resolution measurements of land surface and surrounding coastal regions. This mission will provide data continuity with previous Landsat measurements. Landsat data is used for global change research, regional environmental change studies, and other civil and commercial purposes.

With the EOS main missions, such as AM-1 and Landsat-7 that will be launched in 1999, NASA will begin to turn flight data into information. In addition to the EOSDIS that will produce data products for a wide range of users, NASA is engaging in a variety of activities to extend the utility of Earth Science data to a broader range of users such as regional Earth science applications centers, Earth science information partners, and efforts are under way to fuse science data, socio-economic data and other data sets that can be "geo-referenced" in readily understandable data visualizations.

The first of two cooperative missions with the Russian Space Agency (RSA), the Meteor-3M(1) Stratospheric Gas and Aerosol Experiment (SAGE III) mission, is planned for launch in 1999. This mission will collect global profiles of key gaseous species from the troposphere to the mesosphere. The science team will investigate spatial and temporal variability and investigate the effects of aerosols and clouds on the Earth's environment. The Russian METEOR-3M(2) spacecraft is planned to carry the last planned TOMS into orbit in 2000, providing continuity in the essential measurement of the total column of ozone in the stratosphere. However, due to Russian indications that they cannot meet this launch date, NASA is exploring other options.

Five commercial data purchase contracts were awarded in 1998 through the Commercial Remote Sensing Program. Data products will be developed and delivered over the next two years.

The QuikScat spacecraft is ready for launch and is awaiting a launch opportunity. The planned launch in December 1998 was delayed pending the results of the investigation into the failure of a USAF Titan IV launch vehicle earlier in 1998 and related issues with the Titan II. QuikScat, carrying instruments to collect sea surface wind data, will fill the gap in such critical data between ADEOS 1, which failed in June 1997 after seven months on-orbit, and ADEOS II. The availability of components of the Seawinds instrument originally planned for launch on Japan's ADEOS II was accelerated to fly on QuikScat. At present, QuikScat is scheduled for launch in late April 1999. Japan has yet to decide on the timing and form of an ADEOS II mission (or missions), but Earth Science still intends to fly a Seawinds instrument in that context as the follow-on instrument to QuikScat. This will enable continuity of the ocean winds data. In parallel to this development effort, a data buy solicitation for ocean and wind vector data was completed.

Other planned Earth science launches include the Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat) and the Hyperspectral EO-1 mission in 1999.

The measurements to be made by these and other future Earth science missions as well as current on-orbit missions provide data products that are used extensively in the Earth science program. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM

	FY 1998	FY 1999 (Thousands of Dollars)	FY 2000
AM-1	71,200	31,800	6,200
PM-1	175,900	114,600	119,400
Chemistry-1	110,400	130,400	124,700
Special spacecraft	96,700	116,200	150,000
QuikScat	37,900	10,800	1,100
Landsat-7	74,300	17,000	2,900
Algorithm development	92,300	115,600	127,400
Technology infusion	91,900	90,200	77,600
(New millennium program)	(81,700)	(57,300)	(41,100)
(Sensor & detector/ Technology Initiatives)	(5,500)	(5,500)	(8,900)
(Instrument incubator)	(4,700)	(20,900)	(20,000)
(Advanced Information System Technology)		(6,500)	(7,600)
EOS Follow-on	3,900	4,500	53,900
Total	754,500	631,100	663,200

PROGRAM GOALS

The overall goal of the Earth Observing System (EOS) is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions between them, and how the Earth system is changing. The EOS data will be used to study the atmosphere, oceans, cryosphere, biosphere, land surface and solid Earth, particularly as their interrelationships are manifested in the flow of energy and in the cycling of water and other chemicals through the Earth system.

The EOS program mission goals are to:

(1) Create an integrated, scientific observing system emphasizing climate change that will enable multi-disciplinary study of the Earth's critical, life-enabling, interrelated processes.
(2) Develop a comprehensive data information system, including a data retrieval and processing system.
(3) Serve the needs of scientists performing an integrated multi-disciplinary study of planet Earth and to make Earth science data and information publicly available.
(4) Acquire and assemble a global database for remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

STRATEGY FOR ACHIEVING GOALS

The EOS contributes directly to accomplishing the goal of understanding global climate by providing a combination of observations made by scientific instruments, which will be integrated with the EOS spacecraft, and the data received, archived, processed, and distributed by the EOSDIS. The selection of scientific priorities and data products responds directly to the USGCRP global change science priorities and the assessment by the Intergovernmental Panel on Climate Change of the scientific uncertainty associated with global climate change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning (AM), afternoon (PM), and Chemistry. Beginning in 1999, 2000, and 2002 respectively, the satellites will be flown for a period of six years. Additional observations will be provided by the Landsat-7 mission and will begin in 1999.

Nearly all key EOS missions include international contributions. For example, the AM-1 spacecraft will fly an instrument from Canada (Measurements of Pollution of the Troposphere (MOPITT)) and one from Japan (Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)); PM-1 will include the Japanese Advanced Microwave Scanner Radiation (AMSR) instrument and the Humidity Sounder for Brazil (HSB). In addition, numerous agreements have been signed for joint data exchange and distribution, including cooperation in EOSDIS.

EOS program planning began in 1983 with the definition of the science and mission requirements by the EOS Science and Mission Requirements Working Group (SMRWG). The SMRWG charter was to examine the major Earth science questions for the 1990's and to define the requirements for low-Earth-orbit observations needed to answer these questions on a comprehensive multi-disciplinary basis.

The SMRWG's report, issued in 1984, listed five basic recommendations concerning Earth science in the 1990's:

- A program must be initiated to ensure that the present time series of Earth science data are maintained and continued. Collection of new data sets should be initiated.
- A data system that provides easy, integrated, and complete access to past, present, and future data must be developed as soon as possible.
- A long-term research effort must be sustained to study and understand these time series of Earth observations.
- The EOS program should establish an information system to carry out those aspects of the recommendations that go beyond existing and planned activities.
- The scientific direction of EOS should be established and continued through an International Scientific Steering Committee.

The Earth System Sciences Advisory Committee (ESSAC) was appointed in November 1983 by the NASA Advisory Council to consider directions for NASA's Earth science program. The committee's report, issued in May 1986. recognized EOS as the centerpiece **of** the future Earth science implementation strategy. It stated the following goal of Earth system science: "To obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved. how they function, and how they may be expected to continue to evolve on all time scales." It also identified the following challenge to Earth system science: "To develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity."

The successor to the SMRWG, the EOS Science Steering Committee (SSC), continued the definition of the EOS program and provided an overall implementation strategy in its report issued in 1987. Concurrent with the ***SSC*** work, NASA included the EOS program under a broader Agency initiative termed Mission to Planet Earth, which included other efforts such as the Earth Probe missions and NASA's participation in the International Geosphere Biosphere Program (IGBP) and the World Climate Research Program (WCRP). By proceeding to carry out the recommendations of the SMRWG and the ESSAC, including EOS, the SSC argued that it would be possible to move from a single-discipline research mission to a comprehensive mission addressing all aspects of the Earth as a system. Thus, the concept of an Earth system was adopted as the EOS scientific thrust.

An Announcement of Opportunity (AO) to solicit proposals for EOS investigations was issued in January 1988. The EOS program objectives were based on the requirements and goals of the SMRWG. SSC, and ESSAC. In responding to the AO, the proposers could offer to do interdisciplinary studies that carry out integrated Earth system research leading to the development of comprehensive Earth system models. They could be members of research facility teams (formed to provide scientific guidance for the development of the research Facility Instruments (FIs) and to analyze and interpret data from them). Or they could be Principal Investigators (PI) of proposed instruments and data products. The EOS selection process was completed in February 1989, with the selection of **six** team leaders and 93 team members for the **six** NASA research FIs, 24 instrument PIs, and 29 interdisciplinary team PI leaders to participate in the definition phase of the EOS program.

The EOS Investigators Working Group (IWG), formed in 1989, consists of instrument and interdisciplinary PIs and team leaders to provide scientific advice and guidance for the program. The program scientist (from NASA Headquarters) and the senior project scientist (from GSFC) co-chair the IWG. The working bodies of the IWG include twelve science panels. The chairpersons of each of these panels, together with the program scientist and senior project scientist, constitute the Science Executive Committee (SEC) of the IWG. Membership on the panels is generally open to all EOS investigators, including co-investigators on any EOS investigation and members of EOS FI teams. Scientists outside the group of EOS investigators are also included in the various panels.

The IWG plays a leading role in defining the overall science thrust for the EOS program. It coordinates the research efforts and provides guidance and advice to the EOS program and project, as appropriate, concerning all major scientific issues. It will meet regularly throughout the lifetime of the program.

The EOS study project was established at GSFC in 1983. During the Phase A and B study periods, GSFC and the Jet Propulsion Laboratory (JPL) performed mission, data system and spacecraft studies resulting in a conceptual design of a dual series of spacecraft missions that would satisfy the EOS requirements. The spacecraft were designated EOS-A and EOS-B, with GSFC and

JPL having the respective managerial responsibilities. Following the EOS Non-Advocacy Review (NAR), held in June 1989, management responsibilities for the EOS-B series, as well as the project management role for the execution phase of EOS, were transitioned to GSFC. The Synthetic Aperture Radar (SAR), which was a flight instrument to be launched on EOS-B, was identified as an independent mission, to be managed by JPL, and a candidate for separate program approval. In 1990, responsibility for development of the platform was transferred from the space station program to EOS. EOS management became centralized within the EOS project at GSFC.

Congress approved the EOS program as an FY 1991 budget initiative. The payload for the first flight (EOS-A1) was selected in January 1991, following conceptual design and cost reviews of the selected instruments and IWG Payload Panel recommendations on scientific priorities and synergism. The baseline flight segment consisted of two series of large observatories, EOS-A and-B, in 1:30 PM ascending, sun-synchronous orbit, launched by a Titan-IV with solid rocket motor upgrades from the Western Space and Missile Center (WSMC). Each observatory had a five-year life and each was to be replaced twice to provide a 15-year mission. The budget runout through FY 2000 was $17 billion.

The National Research Council (NRC) advises the federal government through reports of reviews it conducts using its various committees, which involve the broad community of science and technology experts. Prior to the EOS new start approval in FY 1991, their report, "The U. S. Global Change Research Program: An Assessment of FY 1991 Plans," provided a critical review of the EOS program.

In the July 1991, report, "Assessment of Satellite Earth Observation Programs 1991," the NRC was in general agreement with the EOS plan for the large EOS-A observatory and its selected payloads. It expressed concern that the total EOS budget size could lead to potential delays, noted data gaps in key areas, and endorsed the Earth Probe concept. These reviews were the beginning of a series of evaluations of the program to ensure the proper scientific return on the EOS investment.

As part of the FY 1992 budget process, the Committees on Appropriations directed NASA to restructure the EOS program to:

- Focus the science objectives of EOS on the most important problem of global change (i.e., global climate change).
- Increase the resilience and flexibility of EOS by flying the instruments on multiple, smaller platforms rather than a series of large platforms.
- Reduce the cost of EOS through FY 2000 to $11 billion.

In the summer and fall of 1991, NASA conducted a restructuring of the program to meet the congressional mandate. This process included an independent review by the External Engineering Review Committee, which issued its report in September 1991. The process also involved assessment by the scientists who will use the data from EOS, including both the EOS IWG and the EOS Payload Advisory Panel. The EOS project at GSFC conducted studies to determine how the EOS instruments could most effectively be configured on small spacecraft. In December 1991, the NASA Administrator reviewed and approved the restructured EOS program, and in March 1992, NASA submitted its report on the restructured program to Congress. Congress approved the restructured program in 1992.

Recognizing that the subsequent budget environment would not support the complete and timely implementation of the restructured EOS program described in the March 1992, report to Congress, the NASA Administrator directed that the program be rescoped with a goal of further reducing its costs through FY 2000 by 30% to $8 billion. The EOS rescope was completed in June 1992, satisfying the 30% reduction by capitalizing on efficiencies, reducing at-launch science data products, by rephasing work, by increasing international participation, and by deleting the High-Resolution Imaging Spectrometer (HIRIS) flight instrument. As a result of the rescoping process, EOS became recognized by NASA as a cost-driven program.

In the 1995 congressional budget cycle, the EOS budget was reduced by $758.5 million through FY 2000, to $7,243.4 million, of which $131.3 million was due to a funding responsibility transfer.

The EOS rebaselining effort conducted in 1994, with the following results, was reflected in the FY 1996 budget submission:

- Preserve the scientific integrity of EOS and Earth science
- Preserve the measurement complement of the first mission in each series
- Preserve the launch dates for AM-1, PM-1 and Chemistry-1
- Phase EOSDIS development to support missions through FY 2000
- Restore reserves to a prudent level
- Incorporate appropriate technology advancements
- Fit within annual funding guidelines for the EOS program
- Replace major spacecraft at six year intervals

Public Law 102-555 returned the development, operations and data distribution of the Landsat-7 project to the federal government in 1992. It established the Landsat Program Management (LPM) team comprised of the DoD and NASA. DoD was responsible for the acquisition of the satellite and NASA was responsible for the development of the ground system. In the fall of 1993, DoD withdrew from the project. At the direction of the National Science and Technology Council (NSTC), the Office of Science and Technology (OSTP) initiated a review and restructuring of the Landsat-7 project. Under Presidential Decision Directive (PDD)/NSTC-3, the Land Remote Sensing Strategy was established. This strategy implemented a project management structure for the Landsat-7 project, which made NASA responsible for development of the satellite, instrument and ground system, NOAA responsible for operations, and the USGS, in conjunction with the EOSDIS Land Process Distributed Active Archive Center (LPDAAC), responsible for data archive and distribution.

During the EOS rebaselining process, the Landsat-7 project was integrated with EOS. As another aspect of the rebaselining, the EOS science project was reorganized. The funding to support the activities of the EOS instrument investigators and interdisciplinary science investigators was moved to research and analysis. The science algorithm development and maintenance remains in the EOS budget.

During 1995, NASA conducted a comprehensive review of EOS to accomplish a number of interrelated objectives: to substantially reduce EOS life-cycle costs while preserving the basic measurement set; to provide for technology infusion that will be available in time to lower the cost of the follow-on series, to provide new science opportunities through small satellites, and to adjust program management to an evolutionary approach.

This "reshaping" exercise recognized that the first series already employs or advances the state-of-the-art in spacecraft and instruments. Even so, savings achieved in the EOS Data Information System (EOSDIS) implementation and other changes enable some savings and improvements in the first series. These include accelerating Laser Altimetry and Active Cavity Radiometer Irradiance Monitor (ACRIM), by one year, providing a spacecraft for SOLSTICE (previously awaiting a flight of opportunity), and the explicit provision of funding within the EOS budget for new technology missions.

The 1997 Biennial Review completed the shift in planning for future missions (i.e., beyond the EOS first series) that began in the 1995 "reshaping" exercise. Emerging science questions drive measurement requirements, which drive technology investments in advance of instrument selection and mission design. Mission design includes such options as purchase of science data from commercial systems and partnerships with other Federal agencies and international agencies. The result is a more flexible and less expensive approach to acquiring Earth science data.

In the spring of 1998, a Request for Information (RFI) on EOS future missions was released to the broad Earth science community. The RFI responses are being evaluated and will form the basis for redefined future EOS mission profiles with greater detail and higher fidelity cost estimates. After further study and discussion, these mission profiles will be used to focus EOS Announcements of Opportunities (AOs), the first of which is expected for release in 2000.

AM-1

A new generation of Earth science will begin with the launch and checkout in 1999 of EOS AM-1 - one that studies the Earth as a global system. Because the AM-1 spacecraft primarily observes terrestrial features, a morning equatorial crossing time is preferred to minimize cloud cover over land. EOS AM-1 will carry a complement of five synergistic instruments. The Clouds and Earth's Radiant Energy System (CERES) instrument will perform measurements of the Earth's "radiation budget" or the process by which the Earth's climate system maintains a balance between the energy that reaches the Earth from the sun, and the energy that radiates from Earth back into space. The components of the Earth system that are important to the radiation budget are the planet's surface, atmosphere, and clouds. The Multi-angle Imaging Spectroradiometer (MISR) will measure the variation of the surface and cloud properties with the view angle. Meanwhile, the Moderate-Resolution Imaging Spectroradiometer (MODIS) will measure atmosphere, land, and ocean temperature, and moisture profiles, snow cover and ocean currents. The Canadian Measurements of Pollution of the Troposphere (MOPITT) instrument is an infrared gas-correlation radiometer that will take global measurements of carbon monoxide and methane in the troposphere. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provided by Japan, will measure cloud properties, vegetation index, surface mineralogy, soil properties, surface temperature and obtain digital elevation modes. The primary contractors associated with the project are Lockheed Martin Missiles and Space (LMMS) for the AM-1 spacecraft, Raytheon Sensors and Electronic Systems for the MODIS instrument, TRW for the CERES instrument (the instrument has also been flown on the TRMM in 1997 and will fly on the PM spacecraft), and Lockheed Martin Commercial Launch Services for the AM-1 Atlas Centaur/IIAS launch service.

PM-1

The research focus of the PM-1 spacecraft is atmospheric temperatures and humidity profiles, clouds, precipitation, and radiative balance; terrestrial snow and sea ice; sea-surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction. With the emphasis of the instrument complement being cloud formation, precipitation, and radiative properties, an afternoon equatorial crossing is more suitable for acquiring the data. The primary contractors associated with the project are TRW for the common spacecraft to be used for PM-1; Lockheed Martin Infrared and Imaging Systems (LMIRIS) and JPL for the Advanced Infrared Sounder (AIRS) instrument; and Aerojet for the Advanced Microwave Sounding Unit (AMSU) instrument. Japan will provide the AMSR instrument for the PM-1 spacecraft and Brazil will provide a microwave instrument, the HSB. The launch of PM-1 is scheduled for December 2000.

Chemistry

The Chemistry-1 mission focuses on the impact of greenhouse gases on the global climate. The Project is in Phase C/D developments. The Tropospheric Emission Spectrometer (TES) and the Microwave Limb Sounder (MLS), and High Resolution Dynamics Limb Sounder (HIRDLS) have completed their Preliminary Design Reviews (PDR) in 1997 and 1998 and are now reaching a high level of design maturity. The Ozone Measuring Instrument (OMI), an ozone measuring instrument, is contributed by the Netherlands. The OMI has successfully completed its PDR in December 1998. The launch of Chemistry-1 is scheduled for December 2002.

Special Spacecraft

The Special spacecraft will be designed to study atmospheric aerosols, ocean circulation, ice-sheet mass balance, cloud physics, atmospheric radiation properties, and solar irradiance. Ball Aerospace and Technologies Corporation is responsible for developing the Stratospheric Gas and Aerosol Experiment (SAGE III) that is planned to fly on a Russian spacecraft in 1999, if the Russian launch vehicle is ready, and a flight of opportunity planned for an approximate year 2000 to 2001 launch. The SAGE III will take advantage of both solar and lunar occultation to measure aerosol and gaseous constituents of the atmosphere. The Japanese will provide the Advanced Earth Observing System II (ADEOS II) spacecraft for the Seawinds instrument to measure ocean surface wind velocity as a follow-on to the NASA Scatterometer instrument on ADEOS-I and the Seawinds instrument on QuikScat. The Radar Altimetry mission, Jason-1, will be a follow-on to the TOPEX/Poseidon as a cooperative joint mission with the French Space Agency (CNES), with data provided to NOAA for operational purposes. The EOS Laser Altimetry mission was renamed Ice, Clouds and Land Elevation Satellite (ICESat) to denote its primary objectives of measuring ice sheet height and volume for long-term climate variability studies. The EOS ACRIM, will continue the measurement of Total Solar Irradiance (TSI) begun by the ACRIM instruments on the Solar Maximum Mission and UARS. The Total Solar Irradiance Mission (TSIM), is NASA's science contribution (along with launch services) to the joint NASA/Canadian Space Agency SciSat (science satellite) project, and is the follow-on to the EOS ACRIM mission. TSIM has been explicitly designed to meet the science objectives of both NASA and the National Polar-orbiting Operational Environmental Satellite System (NPOESS).

The Earth Science Enterprise is undertaking a study to look at finding efficiencies in the project by studying the feasibility of combining the SAGE III FOO, TSIM and Solstice instruments into a focused solar irradiance/aerosol mission. This approach could allow greater efficiency in accomplishing these investigations through a more integrated effort. This budget provides funding for a generic mission called the Solar Irradiance and Aerosol Mission (SIAM). The composition of the SIAM mission will be determined in FY 1999.

Landsat

The Landsat-7 1998 activities concentrated on recovering from the instrument thermal vacuum test failure in December 1997. By March 1998, the failure was traced to a part in the power supply design, rework and retest of the instrument got under way in March. Rework and re-integration was completed in May and the instrument returned to its test schedule in June. The ETM+ thermal vacuum testing was completed with no anomalies recorded, and was delivered to the spacecraft in September 1998 with a planned launch date of April 1999.

Technology Infusion

The New Millennium Program (NMP) budget reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs through focused technology demonstrations for Earth orbiting missions. Two Headquarters enterprises are coordinating their project plans to do these missions. The Office of Earth Science has joined the Office of Space Science in the New Millennium Program in order to capitalize on common work from core technology development projects and specific spacecraft and instrument studies. The project will identify and demonstrate advanced technologies that reduce cost or improve performance of all aspects of missions for the next century, (i.e., spacecraft, instruments and operations). The project objectives are to spawn "leap ahead" technology by applying the best capabilities available from several sources within the government, private industries and universities. These low-cost, tightly controlled developments, the Earth Observers (EOs), will take more risk in order to demonstrate the needed technology breakthroughs and thus reduce the risk of using that technology in future science missions. Missions will be selected based on their ability to meet the science needs of the future by innovative technology that would also decrease the cost and improve the overall efficiency of space flight missions.

Increased technology work will be pursued in the areas of sensor and detector systems. Emphasis is being placed on developing new capabilities for Earth science sensors and integrated, autonomous, self-calibrating instruments. Studies are being conducted in the areas of differential absorption Light Direction and Ranging (LIDAR) and OH (hydroxyl) radiometer.

The instrument incubator project is expected to reduce the cost and development time of future scientific instruments for Earth science. The instrument incubator project will aggressively pursue emerging technologies and proactively close the technology transfer gaps that exist in the instrument development process. The project will take detectors and other instrument components coming from NASA's fundamental technology development projects and other sources, and focus on combining them into new instrument systems which are smaller, less costly, less resource intensive, and which can be developed into flight models more quickly for future Earth science missions. This includes the key follow-on instruments for the EOS.

EOS Follow-On

The next generation of EOS missions will provide new technology and space systems to meet the scientific needs for the NASA Earth science projects. Systematic and process measurements will be defined to support the five science theme areas. In FY 1999 various EOS Follow-On mission studies will be conducted to further define the candidate missions which are part of the EOS future mission profiles. These studies will help to define the mission parameters needed to focus the AO planned for release in 2000. Trades will be conducted on various approaches to satisfying the measurement requirements defined by the RFI process. The mission studies will also provide a basis for technology needs as an input to technology project planning. New instrument technologies will be tested, validated, and made available to support science proposals for selection of measurements, principal investigators, and instruments for the next EOS missions. All EOS measurements, principal investigators, and instruments will be selected as a result of a broad agency announcement that will include peer review, with the goal of a first planned follow on launch for FY 2004. Launches are expected each year through 2009.

SCHEDULE AND OUTPUTS

Preliminary Design Reviews - Confirms that the proposed project baseline is comprehensive (meets all project level performance requirements), systematic (all subsystem/component allocations are optimally distributed across the system), efficient (all components relate to a parent requirement), and represent acceptable risk.

SeaWinds
Plan: May 1995
Actual: May 1995

Meteor-3M Stratospheric Aerosol & Gas Experiment (SAGE III)
Plan: July 1995
Actual: July 1995

Earth Observer-1
Plan: February 1997
Actual: February 1997

PM-1
Plan: April 1997
Actual: April 1997

Jason
Plan: June 1997
Actual: June 1997

ACRIM
Plan: March 1998
Actual: March 1998

ICESat
Plan: June 1998
Actual: June 1998

Earth Observer-2
Plan: June 1998
Actual: October 1998

Revised schedule due to delays in initiating the selection process

Chemistry-1
Plan: March 1998
Revised: October 1999

Rescheduled following completion of alternative configuration studies.

SOLSTICE
Plan: June 1999

TSIM
Plan: March 1999
Revised: January 1999

Selection of two teams and refinement of schedule

Critical Design Reviews - Confirms that the project system, subsystem, and component designs, derived from the preliminary design, is of sufficient detail to allow for orderly hardware and software manufacturing, integration and testing, and represents acceptable risk. Successful completion of the critical design review freezes the design prior to actual development.

Earth Observer-1
Plan: April 1997
Actual: June 1997

Schedule changed to accommodate a grating spectrometer, which was recently added to the mission

ACRIM:
Plan: January 1998
Actual: January 1998

PM-1 Plan: April 1998 Revised: June 1998	Revised schedule due to late start following resolution of protest first reported in the 1998 budget
Jason: Plan: November 1998 Actual: November 1998	
Earth Observer-2 Plan: January 1999 Revised: April 1999	Revised schedule due to delays in initiating selection process
TSIM Plan: March 2000 Revised: July 1999	Selection of two teams and refinement of schedule.
Solstice Plan: June 1999	
Chemistry Plan: June 1999 Revised: August 2000	Rescheduled following completion of alternative configuration studies.

Instruments Delivered - Confirms that the fabrication, integration, certification, and testing of all system hardware and software conforms with their requirements and is ready for recurring operation. Throughout system development, testing procedures or, as appropriate, engineering analysis have been employed at every level of system synthesis in order to assure that the fabricated system components will meet their requirements.

Landsat-7 Plan: December 1996 Revised: September 1998	Delays due to technical problems (power supply, panchromatic band noise, mirror scan) and inefficiencies at Raytheon
AM-1 last instrument Plan: February 1997 Actual: August 1997	Test anomalies occurred on the MOPITT instrument; which required rework by Canadians.

SAGE-III (Russian) Plan: December 1997 Actual: September 1998	Due to instrument and detector testing problems.
Seawinds Plan: March 1998 Revised: March 1999	Delayed due to launch slip by Japan.
Earth Observer-1 Plan: October 1998 Revised: May 1999	Schedule changed to accommodate the hyperion alternative for providing the hyperspectral capability following failure to provide functioning detectors
PM-1 last instrument Plan: December 1998 Revised: September 1999	Instrument deliveries delayed, first reported in the 1998 budget
Earth Observer-2 Plan: August 2000	
ICESat Plan: October 2000	
Chemistry-1 last instrument Plan: June 2001 Revised: January 2002	Rescheduled following completion of alternative configuration studies.
QuikScat Plan: May 1998 Actual: May 1998	
ACRIM Plan: October 1998 Revised: June 1999	Instrument delivery changed to fit new launch schedule after selection of launch vehicle and spacecraft vendors.
Jason-1 Plan: March 1999	
TSIM Plan: March 2001	

Algorithm Development (Version 2) - Confirms that the second version of the science software necessary for the production of the standard data products for each mission has been developed and is ready to support launch.

AM-1
Plan: February 1998
Actual: February 1998

Aerosol SAGE-III (Russian) Commensurate with the delay in instrument delivery.
Plan: December 1997
Revised: June 1999

SeaWinds
Plan: September 1998
Actual: September 1998

Jason-1 Revised due to delayed selection of science team and revised launch date.
Plan: December 1998
Revised: October 1999

Earth Observer-1
Plan: April 1999

PM-1
Plan: July 2000

Chemistry-1
Plan: December 2001

ICESat Revised due to delay selection of science team.
Plan: July 2002
Revised: January 2001

Launch Readiness Dates - Verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

AM-1 Significant delays in the EOSDIS Flight Operations System (FOS) have resulted in the delay of the EOS AM-1 launch.
Plan: June 1998
Revised: July 1999

QuikScat Plan: November 1998 Revised: April 1999	Delayed due to USAF Titan IV failure investigations and launch site availability conflicts.
Landsat-7 Plan: Dece3mber 1998 Revised: April 1999	Delays due to technical problems (power supply, panchromatic band noise, mirror scan) and inefficiencies at Raytheon
ACRIM Plan: October 1999 Revised: November 1999	Availability of launch vehicle
Aerosol SAGE-III (Russian) Plan: December 1998 Revised: September 1999	Revised to increase mission reliability by enhancing the testing of critical subsystems for the newly developed METEOR spacecraft and Russian funding delays.
Earth Observer-1 Plan: 1998 Revised: December 1999	Schedule changed to accommodate the Hyperion alternative for providing the hyperspectral capability following failure to provide functioning detectors
Seawinds (ADEOS-II) Plan: August 1999 Revised: November 2000	Delayed due to launch slip by Japan.
Jason 1 Plan: December 1999 Revised: May 2000	Delayed to accommodate spacecraft development by French Space Agency (CNES) partner
PM-1 Plan: December 2000	
Earth Observer-2 Plan: January 2001	
Chemistry-1 Plan: December 2002	

ICESat
Plan: July 2002
Revised: January 2002

Due to new catalog spacecraft approach, the launch was originally accelerated by six months.

TSIM
Plan: December 2001

SOLSTICE
Plan: December 2002

ACCOMPLISHMENTS AND PLANS

AM-1

Integration and test of the integrated AM-1 spacecraft was completed in the first quarter FY 1998. Version 1 of the science software was delivered in the second quarter of FY 1998. The second external independent readiness review was held prior to the start of environmental testing of AM-1 (with all instruments integrated onto the spacecraft). Environmental testing was completed in the second quarter of FY 1998. In 1999, the spacecraft will be delivered to the Astrotech commercial launch processing facility at the Vandenberg AFB, California, where system end-to-end testing will be performed and preparation for launch will be completed. Launch is scheduled for no earlier than July 1999.

PM Spacecraft

The PM-1 spacecraft design phase was completed and a successful Critical Design Review was held in June 1998. Fabrication and assembly of the spacecraft is well under way, with a scheduled completion date of June 1999. Integration and test of PM-1 is scheduled to begin in June 1999. Several instruments have completed final assembly and environmental testing. The remainder are scheduled for completion in the Spring of 1999. Instrument delivery to PM-1 is planned for completion in September 1999. The common spacecraft CDR was completed in FY 1998. The common spacecraft will complete fabrication and begin integration and test in 1999.

The integration and test of the EOS PM-1 spacecraft will be completed in FY 2000. Science software deliveries will be completed and ground system and operations preparations will be completed. PM-1 remains on schedule to meet a launch readiness date of December 2000.

(

Chemistry Spacecraft

The Chemistry mission, focusing on the impact of greenhouse gases on global climate has been maturing in terms of instruments design concepts. The HIRDLS, MLS, and TES have initiated Phase C/D development. HIRDLS, MLS, and TES successfully completed PDRs in 1997 and 1998. These instruments are in a detailed design and development phase. Negotiations are under way with the Netherlands for them to provide an OMI. The Chemistry project is in Phase C/D. The OMI being a late addition to the instrument suite for the Chemistry platform is beginning its design and development effort and successfully PDR in late 1998. In 1999 MLS, TES, HIRDLS, and OMI CDRs will be completed, including the engineering models for each. HIRDLS will be in the fabrication phase. A draft version of the science Algorithms Theoretical Basis Document (ATDB) will be completed for TES and MLS and HIRDLS.

The common spacecraft delta CDR specific to the Chemistry Mission is planned for 2000. Ground system operational requirements will also be completed. Each of the Chemistry Instruments will be completing Engineering Model testing and calibration activities, and will begin conducting Flight Model Integration and Test activities during 2000. The MLS and TES Instrument Teams will be delivering Beta Versions of their Science Data Processing (SDP) software during 2000. All of the Instrument Teams will be developing the L-24 Engineering Versions of their SDP software. Fabrication, Assembly and Test of Common Bus subsystems that are also common to the PM spacecraft will be completed during 2000. The Common Spacecraft CDR specific to the Chemistry Mission is also planned for 2000. Ground system operational requirements will also be completed.

Special Spacecraft

The Jason-1 MOU between NASA and CNES was signed in December 1996.. CNES will provide the spacecraft, solid-state altimeter, and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) positioning system. NASA will provide the microwave radiometer, global positioning system and laser retroreflector array. The ground system and mission operations will be shared. NASA will also provide the launch services. Delays in the CNES satellite development program and altimeter development have caused the reschedule the launch of Jason-1 to May 2000. NASA supported a Jason-1 PDR in June 1997 and initiated the Boeing Delta II launch vehicle contract in September 1997. NASA instrument progress was ahead of schedule, with the Jason Microwave Radiometer engineering model component delivered.

The Jason-1 activities for 1998 focused on the completion of the critical design for all flight elements. Engineering model development and test is complete for the technologically difficult instruments, the altimeter and microwave radiometer. The CDRs for these instruments were both held early in 1998 to support a system-level CDR for the satellite in June 1998. Flight models of the instruments were built during the second half of 1998 for delivery to the payload integration activity at CNES next year. Another critical activity under way in 1998 was the design and development of the Dual Payload Attach Fitting (DPAF) an addition to the launch vehicle structure that would accommodate the dual Jason-1/TIMED payload on the Delta II launch vehicle.

CNES held the system-level CDR for the Jason-1 mission with NASA support in the fall of 1998. Simulators or engineering models of all the instruments will be delivered to CNES, who will perform platform and payload integration and test as separate activities. The flight models of all the instruments will be delivered by mid-1999 and the test readiness review for the ground system will be held in June 1999. Satellite-level integration and test is scheduled to being by mid-summer 1999. CNES will ship the integrated satellite for Jason-1 to the Western test range and launch is scheduled for May 2000 on the Delta launch vehicle, co-manifested with NASA's TIMED space science satellite. After launch and a 60-day checkout, normal mission operations are scheduled to being, including formation flying with the TOPEX/Poseidon satellite, to provide cross correlation for scientific trend analysis of the sea-surface height.

The ICESat team selected Ball Aerospace and Technologies Corporation's spacecraft contractor from the Goddard Space Flight Center's catalog of industry standard spacecraft in February 1998. The GeoScience Laser Altimeter System (GLAS) PDR was held in June 1998 and followed by a successful confirmation review by an independent team of the overall mission. The ICESat activities for 1999 will focus on flight hardware fabrication. The mission approach to using the catalog spacecraft allows a streamlined development schedule, so that the traditional PDR, CDR sequence was modified to a single Mission Design Review which is scheduled for early FY 1999. The GLAS engineering model will be tested and delivered to the spacecraft and fabrication of the flight model will begin. The launch vehicle for ICESat will be selected in 1999. The critical activities for ICESat in 2000 will be spacecraft flight hardware environmental testing. The beta version of the ICESat algorithms will be delivered to EOSDIS for testing of the data product generation. Due to using the new catalogue spacecraft approach, the launch has been accelerated six months.

The Solar Stellar Irradiance Comparison Experiment (SOLSTICE) continued to make progress in Phase B towards a December 2002 launch. SOLSTICE successfully completed a conceptual design and cost review in March 1998 and LASP issued a request for proposals for a SOLSTICE spacecraft. In FY 1999 SOLSTICE will complete final design of the three flight instruments and select the spacecraft contractor. The SOLSTICE mission design review, combining PDR and CDR, will be held in June 1999. The key milestone for SOLSTICE in FY 2000 will be the spacecraft design review scheduled for the second quarter.

There are two Stratospheric Gas and Aerosol Experiment (SAGE version III) instruments being manufactured for long-term monitoring of ozone and aerosol. The instrument is in the final phase of test and development. The first SAGE III mission is planned to fly on a Russian Meteor-3M spacecraft in 1999. The instrument was completed in 1998 and will be shipped to Russia in March 1999, as long as the Russian launch vehicle is ready. The second mission is a Flight of Opportunity (FOO), planned for an early turn of the century launch once an affordable opportunity is identified. The logistics, testing, integration, and launch plans are in place with the Russians for the Meteor-3M spacecraft for the first mission. The two SAGE III instruments were delivered in 1998.

The Seawinds CDR was completed in January 1996. The Seawinds instrument continued to undergo protoflight model fabrication and assembly during FY 1998. The Seawinds instrument activities will consist of integration and test of the instrument. The protoflight model is scheduled for delivery to Tsukuba, Japan in March 1999 for a November 2000 launch on the ADEOS II spacecraft by a NASDA H-II rocket from Tanegashima, Japan.

The Active Cavity Radiometer Irradiance Monitor (ACRIM) continued to make excellent progress on instrument fabrication and spacecraft development in 1998, on schedule for a launch in FY 1999. The ACRIM spacecraft was manifested on a Taurus launch vehicle (dual launch with Korean Spacecraft). The ACRIM mission will make final preparations for launch in FY 1999 including integration of the ACRIM payload onto the Orbital spacecraft and installation of the ACRIM ground station at Table Mountain California. ACRIM will hold a Mission Readiness Review in September 1999. In FY 2000 NASA will launch ACRIM (October 99) and begin the five-year mission.

NASA awarded contracts for the Total Solar Irradiance Mission (TSIM) Phase B design studies to two contractors in July 1998: the University of Colorado, Laboratory for Space and Atmospheric Physics and the Naval Research Laboratory. In the first quarter of FY 1999 the two mission teams will present their mission design reviews. Based on the evaluation of the two TSIM designs, the Associate Administrator will select a single contractor in January 1999 to continue developing the TSIM mission. In June 2000 TSIM will hold a CDR on-track for a launch in December 2001.

In an effort to align related science investigations while reducing overall costs, the Office of Earth science is undertaking a study to look at the feasibility of combining the SAGE III FOO, TSIM and Solstice instruments into a focused solar irradiance/aerosol mission. A team has been established to evaluate the probability of this mission with the findings culminating in the second quarter of FY 1999.

QuikScat

The QuikScat mission will fill the ocean-wind vector data gap created by the loss of the NASA Scatterometer (NSCAT) on the Japanese Advanced Earth Observing Satellite (ADEOS-I) spacecraft. The NSCAT instrument ceased to function when ADEOS-I failed in 1997. The follow-on Scatterometer, Seawinds, is scheduled for launch on the Japanese ADEOS-II spacecraft in November 2000. Spares from the Seawinds instrument were used to assemble the QuikScat Scatterometer instrument. Ball Aerospace and Technologies Corporation of Boulder, Colorado was selected in 1997, to provide the QuikScat spacecraft. Ball was selected via the Indefinite Delivery Indefinite Quantity (IDIQ) rapid delivery spacecraft contract. QuikScat will be completed in 1998 and ready for launch, pending launch site availability. The most likely available launch date, using a Titan-II from Vandenberg Air Force Base, is presently April 1999.

Lightning Mapper

During FY 1998 significant progress was made on the Lightning Mapper Sensor (LMS) including design of key electronics. This culminated in a successful Systems Requirements Review. Procurements were awarded for two key subsystems of LMS. The advancements that will be made on the Charged Coupling Device (CCD) and the optics assembly through these procurements will contribute substantially to the risk mitigation of the final instrument.

Landsat

After the original instrument anomalies were corrected, the Landsat-7 ETM+ instrument was delivered again in September 1998. Spacecraft integration and testing continues. Testing was completed in the Fall of 1998. End-to-end test of the spacecraft and ground system will be completed in early FY 1999.

The spacecraft will be delivered to California Space Port commercial launch processing facility at the Vandenberg AFB where systems end-to-end testing will be performed and preparation for launch will be completed. Launch is planned in April 1999.

While the original plans called for the transition of Landsat-7 operations to NOAA after launch, there is now an alternate proposal being considered where NASA would temporarily operate the satellite in preparation for transition of full operational responsibilities to the US Geological Survey (USGS).

Technology Infusion

The New Millennium Program (NMP) focuses on identifying and demonstrating, in flight, advanced technologies that reduce cost or improve performance of spacecraft and instruments. The NMP emphasizes partnering with industry, academia and other Government agencies.

The Earth Observer (EO-1) Advanced Land Imager is the first mission selected under the NMP series and is scheduled for launch in 1999. The EO-1 consists of an Advanced Land Imager (ALI) instrument, a spacecraft, and numerous advanced technologies as an integral part of the mission. The EO-1 is in Phase C/D and has completed CDR.

Due to the manufacturing difficulties at the ALI detector contractor, the hyperspectral imaging capability of the ALI was descoped to multispectral imaging only to preserve the overall mission schedule and cost. The decision was made in the summer of 1998 to continue the hyperspectral capability, however, through another contractor's design. This capability will augment the ALI but will not impact the existing design. The hyperspectral functionality will be provided by an additional module called Hyperion to be completed by TRW. The Hyperion delta CDR was completed this year. In 1999 the EO-1 mission will be launched.

Following selection, development of the Space-Readiness Coherent Lidar Experiment (Sparcle) was started in May 1998 as EO-2. The Sparcle mission is scheduled for launch in 2001. The mission will fly an infrared laser in the cargo bay of the Space Shuttle to determine if a space-based sensor can accurately measure global winds within Earth's atmosphere from just above the surface to a height of about 10 miles. The measurement in this region of the atmosphere may lead to improved weather forecasting and a better understanding of climate-related events such as El Niño.

The Announcement of Opportunity for the EO-3 mission was released in 1998; mission concept selection is planned in early 1999.

The advanced technology initiatives activities will focus and refine ESE technology requirements, including system trade studies and the development of technology roadmaps. Architectural concepts developed under the advanced concepts element are carried forward to determine the specific system, subsystem and component performance metrics required for their implementation.

This element also advances key component and subsystem technologies required for the next generation of process and monitoring missions. An example is the current sensors and detectors project that includes the development of LIDAR technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing. These activities are complementary to the Space Science Enterprise-supported Cross-Enterprise Technology Development Program (CETDP), NASA's primary advanced technology program developing component and subsystem technologies at early stages of maturity. While CETDP has the charter for generic technologies with value to multiple NASA enterprises, ESE's advanced technology initiatives element is focused on technologies specific to ESE needs.

For 1998 the advanced technology initiatives element include the development of LIDAR technologies for profiling winds and chemical constituents within the Earth's atmosphere, spectrometers that can return high quality EOS level-2 science products at lower total mission cost and radiometers for passive microwave and millimeter wave remote sensing.

Also under this element, systems trade studies were conducted in 1998 in the following areas:

- Visible/Near-IR Remote Sensing Options
- High Data-Rate Instrument Requirements
- Systems Issues on Formation and Constellation Flying
- LIDAR Studies
- Molniya Earth Orbit (MEO) Applications-Science/Cost Benefits
- Geostationary orbit (GEO) Missions
- Advanced Microwave Radiometry
- GPS Surface Reflection Technology for Space
- Tropospheric Measurement Options

The Instrument Incubator Project (IIP) supports the development of new instruments and measurement techniques from paper studies through laboratory development and ground or air validation. NASA Research Announcements (NRAs) are used as the vehicle to search the combined public and private science/technology community for the best new ideas and development capability. NASA received 123 proposals of which 27 have been selected and are planned to be on contract by February 1999. Selected projects include three from industry, six from NASA field centers, eight from universities and ten from national laboratories. Areas for instrument development within the project include land-cover and land-use change and global productivity research; seasonal-to-interannual climate variability and prediction; natural hazards research and applications; and long-term climate observations -- natural variability and change research, and atmospheric ozone research.

The advanced geostationary study effort has been evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advance geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities have been closely coordinated between NASA and NOAA.

EOS Follow On

In the spring of 1998, a Request for Information (RFI) on EOS future missions was released to the broad Earth science community. The RFI responses were evaluated and form the basis for redefining future EOS mission profiles with greater detail. After further study and discussions, these mission profiles will be used to focus EOS Announcement of Opportunities (AOs), the first of which is expected for release in 2000.

Funds will be used to carry selected instruments through detailed design and engineering model development. In FY 1999, fabrication of CERES flight model number 5 will continue; the instrument provides Earth radiation budget measurements. Other instrument studies will be conducted in FY 2000 in accordance with the Announcements of Opportunities that will be issued.

One study under way is examining the feasibility of developing and deploying an atmospheric temperature and humidity sounding system which meets both the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) and NASA scientific requirements for obtaining atmospheric temperature and moisture profiles. This sounding system will include an infrared sounder and a microwave sounder. The system is anticipated to be flown and operated on the NPOESS-C1 spacecraft and subsequent NPOESS and/or European METOP spacecraft. An initial implementation agreement between NASA and the NPOESS Integrated Program Office was signed in August of 1998.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH OBSERVING SYSTEM DATA INFORMATION SYSTEM

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Earth Observing System Data Information System............	210,100	261,700	231,500

PROGRAM GOALS

The goals for the EOS Data Information System (EOSDIS) are the development and operation of a highly integrated system which can: (1) operate the EOS satellites; (2) acquire instrument data; (3) produce data and information products from the EOS, to preserve these and all other Earth science environmental observations for continuing use; and (4) make all these data and information easily available for use by the research, education, government agencies and all those who can benefit from them in making economic and policy decisions. The EOSDIS facilitates the goals of Earth science by enabling the public to benefit fully from increased understanding and observations of the environment.

STRATEGY FOR ACHIEVING GOALS

The EOSDIS is based on an evolutionary design to develop capabilities with the phased deployment of the EOS satellites and to enable adaptation to changes in user needs and technology. NASA is making extensive use of prototypes to assure that EOSDIS will effectively meet the needs of the satellites and users. A limited amount of technology development and adaptation is focused specifically on meeting EOSDIS evolutionary needs while relying on other projects at NASA and other agencies to fund technology development efforts of a more generic nature, i.e., communications technology. An initial version of the system, Version 0, implemented at eight Distributed Active Archive Centers (DAACs) and through cooperative efforts with NOAA, the USGS, and international partner space agencies, became operational in 1994.

Plans for development of subsequent versions of the EOSDIS have been redrawn. Due to continuing problems and schedule delays with completion of the Science Processing Software System (SPDS) and the Flight Operations System (FOS), two important components of the EOS Core System (ECS), we have focused ECS work on operational support for the near-term missions (AM-1 and PM-1) and with post-launch deliveries of software restoring some of the originally planned capability.

EOSDIS development has been divided into four major components: The EOS Data and Operations System (EDOS) which has been developed by TRW, the EOSDIS Backbone Network (EBNet) which has been developed in-house by GSFC with support contractors, the ECS which is under development by Raytheon, and the DAACs. The EDOS receives the raw data stream from the satellites, separates the data by instruments, and performs the initial processing (packet restoration and temporal ordering) and back-up archiving. The EBNet delivers the real-time data to and from the operations control centers and the science data to the DAACs described below. The ECS includes the FOS, which provides satellite and instrument command and control, and the SDPS, which provides the systems to process the EOS science data and integrate the EOSDIS user functions. The DAACs currently have a limited operational capability using EOSDIS Version 0. The EOSDIS Independent Validation and Verification (IV&V) contract is with Intermetrics Systems Services Corporation.

The EDOS element of EOSDIS has been developed and a flight ready version has been installed and tested. The EDOS systems are ready to support the launch and operations of the AM-1 satellite. The EDOS consists of a TDRSS ground station at White Sands Complex (WSC) and back-up polar ground stations (PGS) in Alaska and Norway. The raw satellite data will be sent from the ground stations to the Level-0 processing center at Goddard Space Flight Center, which will process the data and send it to the DAACs. EOS missions following AM-1 will not use the WSC TDRSS ground stations, but will rely on the PGS.

Using the ECS, the eight DAACs will process the raw data from the satellites into useful science products, handle user product searches, requests, orders, and distribute data and information directly to the user community. The DAACs also archive all Earth science data and information for future use. To better serve the user community, each DAAC focuses on the data needs of a specific segment of the user community. A user-working group (advisory panel) guides each DAAC.

The eight DAACs are:

- Alaska Synthetic Aperture RADAR (SAR) Facility, University of Alaska Geophysical Institute, Fairbanks, Alaska
- Earth Resources Observation System (EROS) Data Center (EDC), U.S. Geological Survey, Sioux Falls, South Dakota
- Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
- Langley Research Center, Hampton, Virginia
- National Snow and Ice Data Center, University of Colorado, Boulder, Colorado
- Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee
- Socio-Economic Data and Applications Center (SEDAC), Lamont-Dougherty Earth Observatory, Columbia University, Palisades, New York

Currently, EOSDIS Version 0 allows direct access to selected pathfinder data holdings from the USGS and NOAA. Relationships with Canada, Japan, Russia, Israel, Australia and several European countries have been established for the exchange of data for EOSDIS. Many multi-agency efforts, in addition to the NASA EOSDIS, are working to improve data availability to the public, especially in the Interagency Working Group on Data Management for Global Change and the Federal Geographic Data Committee.

In response to the recommendations by the NRC Board on Sustainable Development, NASA is currently prototyping a new organizational concept for data product generation and distribution. NASA has selected institutions to form a working prototype environmental information federation. The federation will develop concepts for data set interoperability and collective management of a data system, comprised of dispersed, nominally independent data centers.

In light of difficulties in development of the SDPS, NASA has also begun moving responsibility for processing some of the critical EOS Standard Data Products to the EOS Instrument Teams (ITs). The teams have proposed to process the EOS data at their institutions leveraging their NASA provided Science Computing Facilities.

SCHEDULE AND OUTPUTS

EOSDIS Version 1 Plan: January 1997 Revised: Replaced	Provide support for science data processing, archival, and management of the data from the two EOS instruments operating on the TRMM spacecraft. The ECS contractor failed initial test readiness for EOSDIS Version 1 and NASA issued a Stop Work Order. Replacement systems were developed at GSFC and LaRC, (extended "Version 0" in-house system), and the systems are performing successfully.
EOSDIS Version 2 Plan: October 1997 Revised: January 1999 through December 1999	Provide support the launch of AM-1 and Landsat-7. Technical difficulties by the ECS contractor have required a descope in the original requirements planned for Version 2. NASA has issued a Request for Proposal to Raytheon for a reduced requirements set (A+). The requirements will be provided in a set of incremental deliveries beginning in January 1999 and ending in December 1999. The first increment provides for support for launch of Landsat-7 and AM-1, while the additional increments provide for increasing user services and processing capacity is under way.
EOSDIS Version 3 Plan: December 1999 Revised: June 2000	Provide science processing and flight operations support for PM-1. Will support flight operations and science processing, but with descoped capability.
EOSDIS Version 4 Plan: December 2000	Provide science processing and flight operations support for CHEM-1. Will support flight operations and science processing, but with descoped capability. Provides final increment of ECS A+ requirements.

Providing broad and efficient access to data products is key to meeting the Agency mission of advancing and communicating scientific knowledge. The successful functioning of EOSDIS is essential to the accomplishment of all three of Earth science's strategic goals. Three key indicators of DAAC performance are the volume of data archived (approximately 180 terabytes at the end of FY 1998), the number of users accessing the DAACs (over 1 million distinct users accessing the DAACs in FY 1998), and the number of data products delivered in response to user requests (approximately 4.5 million data products delivered in FY 1998).

ACCOMPLISHMENTS AND PLANS

The EOSDIS suffered major development delays in 1998 that resulted in the inability to support the on-time launch of the AM-1 spacecraft. The Flight Operations Segment (FOS) development had a significant failure in March 1998 that resulted in slip of over 12 months in critical launch support capability. Since then, performance stability has been achieved in three of the four major subsystems: command management, planning and scheduling and data management. Performance and schedule problems with the command procedure execution software (used for real time command and control of spacecraft) have persisted, and Raytheon has made the decision to replace this segment of the system with a Raytheon-developed spacecraft control system called "Eclipse".

Raytheon's development of the EOSDIS Core System (ECS) Science Data Processing System (SDPS) also continued to have critical schedule delays and cost overruns. The delays in SDPS are attributable to two key factors: 1) ambitious requirements and the overall complexity in the design of the system, and 2) the high rate of turnover in information technologist personnel (Raytheon has experienced an annual turnover greater than 30% since contract start). The current schedule for achieving all planned capabilities for AM-1 and Landsat-7 is now three years later than the contract date, and this assumes that the development staff is maintained at current levels instead of declining in FY 1999 as planned under the baseline schedule. Due to budget overruns, the requirements for the SDPS have been significantly descoped and system capabilities were prioritized and partitioned into incremental software deliveries. The first delivery of critical software needed to support AM-1 launch was delivered to the DAACs in July 1998 and testing of the code is under way. Since June, numerous deliveries of "patches" have been delivered to fix problems discovered in testing. NASA has formulated a plan that will ensure delivery of the remaining essential ECS capability needed to support AM-1 data processing and AM-1 and Landsat-7 archiving, while containing further cost overruns. This plan includes the potential transition of responsibility for some higher-level data products to the Instrument Teams where appropriate. NASA also began planning a strategy for future implementations of the enterprise data information systems and services. A team comprising NASA managers and science and data system experts was selected to perform a study establishing a roadmap for future data system development.

Other elements of EOSDIS needed to support the AM-1 mission continued on schedule and within budget. The EOS Data and Operations System (EDOS) was delivered and is undergoing acceptance testing, including end-to-end tests with the spacecraft, to support command uplink and data acquisition. The GSFC and LaRC DAACs have successfully supported science processing and data management for the CERES and LIS instruments on TRMM since the TRMM launch in November 1997.

The Environmental Information Federation experiment was officially begun in 1998 with the selection of 24 Working Prototype Earth Science Information Partners (WP-ESIPs) early in the year. The WP-ESIPs held their first organizational meeting in May 1998 and have begun working on issues of collective management and data set interoperability. The 24 WP-ESIPs in the Federation experiment represent the broad science and applications community and include representatives from educational, industry, regional governments and consortium, and NASA data centers. Implementation of the federation is being carried out in parallel with the development of EOSDIS and the Distributed Active Archive Centers (DAACs).

A key focus in 1998 was a review of the eight DAACs by the National Research Council. The NRC reviewers visited each DAAC and assessed its effectiveness through interviews with DAAC customers. NRC is currently finalizing their report on the DAAC peer review.

In FY 1999, EOSDIS will finish development of the FOS using the Eclipse software to support the launch of AM-1 in the third quarter of 1999. The EOSDIS will have several key system deliveries in 1999. The ECS FOS needed for launch support of the AM-1 spacecraft (using the eclipse software) will be delivered and tested in time to support a launch of AM-1 no earlier than May 1999. The SDPS delivery needed to support launch will complete end-to-end testing at the DAACs in January 1999. A second delivery of the software to provide automated support as data flows reach operational levels, to prepare for Y2K, and to support remaining external data sources and higher level products will occur in June 1999. During 1999, selected Instrument Teams (MODIS and MOPITT) will complete the development of their Science Investigator Processing Systems (SIPS) to process some of the higher level EOS standard data products. EOSDIS will begin processing, archiving and distributing data from Landsat-7 and AM-1. By the end of the year, the DAAC archive volume, user accesses, and product deliveries should all be increasing significantly.

The Federation Experiment and the Working Prototype Earth Science Information Partners will be in full swing in 1999. NASA will begin evaluating the federated approach as a model for supplying future earth science data information systems and services and the early results from the Federation Experiment will be factored into the ESE data systems and services strategic planning efforts. The strategy team will complete their study and issue an ESE data systems and services implementation plan in late spring.

Another key milestone for 1999 will be the issuance of the NRC report on the peer review of the ESE Distributed Active Archive Centers (DAACs). The NRC Committee on Global Environmental Data will issue their report in January 1999. A NASA management team will evaluate the report and make recommendations regarding DAAC certification to the Associate Administrator for Earth science.

In FY 2000, operations and continued development of the EOSDIS will be the primary tasks. Additional EOSDIS Core System (ECS) software deliveries in FY 2000 will provide additional capabilities to AM-1 and Landsat-7 data users to facilitate search and access to a growing, complex global data base. A key milestone will be the further development of the EOSDIS to support the requirements for the PM-1 and ICESat missions scheduled for delivery in June 2000. Higher level processing of the science data products from PM-1 will be accomplished at the DAACs or by the PM-1 science teams at their institutions as appropriate, while the EOSDIS DAACs will provide data archival, distribution, and user support.

The Federation Experiment will enter its final year in 2000. The WP-ESIPs will be busy completing their science data set productions and achieving smooth operations as a federation. NASA will complete their evaluation of the experiment and decide on the feasibility and strategy for evolving EOSDIS into a federated architecture.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH PROBES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Total Ozone Mapping Spectrometer	6,000	4,900	4,900
Tropical Rainfall Measuring Mission	900	0	0
Earth System Science Pathfinders	22,800	62,200	75,200
Lewis & Clark	1,400	100	0
LightSAR	0	5,000	20,000
Experiments of opportunity	2,900	2,500	1,000
Triana	900	35,000	35,100
University Class Earth System Science	0	0	2,000
Total	34,900	109,700	138,200

PROGRAM GOALS

The Earth Probes program is the component of Earth science that addresses unique, specific, highly-focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts or technical innovation, and to complement the Earth Observing System by providing the ability to investigate processes that require special orbits or have unique requirements. The currently approved Earth Probes are the Total Ozone Mapping Spectrometer (TOMS), Tropical Rainfall Measuring Mission (TRMM), Triana, Earth System Science Pathfinders (ESSP), and LightSAR. NASA plans to add the University Class Earth System Science (UNESS) pathfinders to the Earth Probes program.

STRATEGY FOR ACHIEVING GOALS

TOMS

The scientific objectives of the TOMS project are to measure the long-term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (flight model 1) on Nimbus-7 and continued with the TOMS instrument (flight model 2) on a Russian Meteor-3, launched in 1991, a TOMS (flight model 3) launched on the Japanese ADEOS in 1996 and the Earth Probe spacecraft also launched in 1996. The remaining development TOMS project consists of one instrument (flight model 5, designated FM-5). The FM-5 has been completed, is in storage, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has indicated that it cannot meet that launch date. Presently, the Agency is in the process of exploring other options.

Earth System Science Pathfinder

The Earth System Science Pathfinder (ESSP) is a science-driven project intended to identify and develop in a short time, small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current projects. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the Earth science program. By launching ESSP missions on a regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion, permitting a continual improvement in our understanding of the Earth system and the processes that affect it.

The first two ESSP missions and an alternate mission were selected in March 1997. The Vegetation Canopy Lidar (VCL) mission, led by a University of Maryland, College Park Principal Investigator, completed Phase B and has begun its fabrication phase with an expected launch date of February 2000. The second mission, Gravity Recovery and Climate Experiment (GRACE) which is led by a Principal Investigator from the University of Texas at Austin with significant participation by the German Aerospace Center (DLR), is in an extended Phase B with launch expected in June 2001. A minimum amount of funding is being provided to the Chemistry and Circulation Occultation Spectroscopy Mission (CCOSM) to maintain this spacecraft as an alternate to replace VCL or GRACE if significant difficulties develop.

The second ESSP announcement of opportunity was released in the third quarter of FY 1998, with selection in December, 1998. NASA has chosen for development one primary and two alternate small spacecraft missions. The Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations – *Climatologie Etendue des Nuages et des Aerosols* (PICASSO-CENA) mission, led by NASA's Langley Research Center will be the next ESSP mission scheduled for launch in 2003. PICASSO-CENA is designed to address the role of clouds and aerosols in the Earth's radiation budget. It will employ innovative light-detection and ranging (LIDAR) instrumentation to profile the vertical distribution of clouds and aerosols, while another instrument will simultaneously image the infrared emission of the atmosphere. During the daylight half of its orbit, PICASSO-CENA will measure the reflected sunlight in an oxygen absorption band and take images of the atmosphere with a wide-field camera. The total estimated mission cost of PICASSO-CENA, including launch vehicle, is $173.5 million, of which NASA will provide $117.4 million. PICASSO-CENA will be launched in 2003. It consists of a partnership between Langley Research Center, France's Centre Nationale D'Etudes Spatiale (CNES), the Institute Pierre Simon LaPlace, Hampton University of Hampton, Virginia (a Historically Black University), the Ball Aerospace and Technology Corporation and the Goddard Space Flight Center. France is providing a PROTEUS spacecraft, the infrared imaging system, and science analysis support.

In addition, NASA has chosen two additional missions, CloudSat and the Volcanic Ash Mission (VOLCAM), for further study at the present time. Based on the study results, designed to mitigate several areas of risk identified during the evaluation, NASA may select one of these missions for full development, and the other as the alternate mission. NASA intends to solicit another set of ESSP missions in the fall of 2000.

Lewis & Clark

The Lewis and Clark missions were intended to be a new way of doing business for NASA with the satellites being developed, launched and delivered on orbit in 24 months or less with minimal government oversight. The two missions were to demonstrate different land imaging capabilities and other measurements of scientific interest to Earth science. The Lewis mission was a medium resolution hyperspectral instrument.

The Lewis spacecraft was built by TRW. Lewis was launched in August 1997. Shortly after launch communications with the spacecraft were lost. Clark was planned to carry 36 new technologies including composite structures, advanced avionics, high-efficiency power systems, and a high resolution multispectral imager. The Clark spacecraft was built by Orbital, formerly CTA Space Systems of Rockville, Maryland, as part of the small spacecraft technology initiative program. In February 1998 after extensive reviews, NASA terminated the Clark Earth science mission due to mission costs, launch schedule delays and concerns over the on-orbit capabilities the mission might provide. NASA has retained the launch vehicle services. Disposition of the Clark assets is currently under review.

LightSAR

The LightSAR project is consistent with direction included in House Report 104-812 which stipulated that NASA's FY 1998 budget include additional funding to accomplish this project. LightSAR is a proposed free-flying, Earth-observing, lightweight, synthetic aperture radar (SAR) mission. It could be used as part of NASA's long-term investment in the development and prosperous use of imaging radar science and technology in the public and private sector. Past spaceborne radar missions have established the vast potential of imaging radar for expanding scientific knowledge of the Earth and planets. LightSAR could demonstrate new technologies that reduce the cost and enhance the performance of SAR missions and could contribute to the next level of expansion for the U. S. commercial remote sensing industry. Industry cost sharing is required before the program can proceed.

Triana

The Triana mission is an Earth observation spacecraft to be located at the Sun-Earth L1 point providing a near-term real time, continuous high definition color view of the full sun-lit disc of the Earth.

During 1998 the mission was studied at GSFC and an Announcement of Opportunity (AO) was released by NASA Headquarters in July soliciting proposals for full Triana mission implementation. A selection was made in November for the Scripps Institution of Oceanography to build and conduct the Triana mission. Triana will carry the Earth Polychromatic Imaging Camera built by Lockheed Martin Advanced Technologiy Company, a radiometer built by the National Institute of Standards and Technology, and a plasma magnetometer that measures solar wind built by GSFC and the Massachusetts Institute of Technology. Launch is scheduled for December 2000.

Experiments Of Opportunity

This project offers a capability to undertake short duration flights of instruments on the Space Shuttle and other platforms. The Earth Science Enterprse has used the capability of Shuttle/Spacelab development in the important areas of design, early test and checkout of remote sensing instruments for free flying missions, and short-term atmospheric and environmental data gathering for scientific analysis. Instrument development activities have supported a wide range of instrumentation, tailored for Space Shuttle and airborne missions.

UNESS

The University Class Earth System Science pathfinder (UNESS) project consists of spaceborne investigations of modest science scope. These investigations will be lead by U.S. university principal investigators with significant student involvement. The Announcement of Opportunity is planned for release in 1999, which is expected to lead to an award of four phase A studies. These studies will result in a selection of two missions for launch in 2001 and 2002.

SCHEDULE AND OUTPUTS

Launch Readiness dates – verifies that the system elements constructed for use, and the existing support elements, such as launch site, space vehicle and booster, are ready for launch.

Vegetation Canopy Lidar
Plan: 1999
Revised: May 2000

The Vegetation Canopy Lidar (VCL), the ESSP mission 1, is scheduled to launch in May 2000. The later launch date reflects the delay in initially selecting and contracting the first ESSP missions.

Triana
Plan: December 2000

PICASSO-CENA
Plan: 2003

Gravity Recovery and Climate Experiment
Plan: June 2001

The Gravity Recovery and Climate Experiment (GRACE) scheduled to launch in 2001.

ACCOMPLISHMENTS AND PLANS

The first ESSP announcement of opportunity was released in FY 1996 and the selection occurred in March 1997. The first two missions are the Vegetation Canopy Lidar (VCL) and the Gravity Recovery and Climate Experiment (GRACE). The Earth Science Enterprise selected three small spacecraft missions as a result of the second ESSP AO. The primary mission is PICASSO-CENA (Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations - Climatologie Extendue des Nuages et des Aerosols. This is a joint mission with NASA's Langley Research Center and the Institut Pierre Simon Laplace, Paris, France. The instruments on PICASSO-CENA are designed to address the role of clouds and small atmospheric particles known as aerosols and their impact on Earth's radiation budget. The spacecraft is planned for launch in 2003.

In addition to the PICASSO-CENA mission, NASA has also selected two additional ESSP missions, CloudSat and Volcanic Ash Mission (VOLCAM), as alternate missions. These two missions will proceed through an extended development and technology assessment prior to the decision of which mission will be the primary and alternate. The CloudSat mission is focused on understanding the role of thick clouds in the Earth's radiation budget. This mission will use advanced cloud profiling to provide information on the vertical structure of highly dynamic tropical cloud systems. VOLCAM is a pathfinder mission for demonstrating the operational and scientific applications of monitoring volcanic clouds and aerosols from a geostationary orbit.

The LightSAR project made substantial progress in 1998. JPL, Stennis Space Center, and four independent industry teams completed detailed studies that defined free-flying Earth observing lightweight synthetic aperture radar (SAR) missions that could deliver Earth science data, validate valuable new technologies, and lead the next level of expansion for the U.S. commercial remote sensing industry. The industry studies concluded that LightSAR could establish U.S. leadership in SAR science, technology and commercial remote sensing by providing greater capabilities at significantly lower cost than any existing or planned free-flying SAR systems. The study also concluded that industry is ready to participate and invest in LightSAR and create long-term businesses that become sustained providers of valuable science and commercial remote sensing data. Industry cost sharing is required before the program can proceed.

In preparation for project start, a payload technology alliance was formed in March 1998. Through the alliance, the best available SAR technologies in the public and private sectors are being developed and validated. This alliance also provides for shared funding contributions as well as technology. These activities are providing early risk mitigation of the critical technologies that will enhance the performance and reduce the mass and cost of LightSAR. A draft AO was released on November 25, 1998 for comments. It will be officially released in January 1999. Proposers will have 45 days from the official AO release date to prepare and submit their proposals.

The Experiments of Opportunity Program supported the STS-87 mission, which was launched in November 1997, carried the Shuttle Ozone Limb Sounding Experiment (SOLSE) and the Limb Ozone Retrieval Experiment (LORE) instruments. The SOLSE shuttle flight successfully demonstrated that the task of limb scatterometry could be used for high-vertical resolution ozone profiles in the lower stratosphere.

Experiments of Opportunity Program is the funding source for NASA's participation in the *Satellite de Applicaciones Cientificas-C* (SAC-C) mission. SAC-C is a joint mission between NASA and the Argentine Space Agency (CONAE). The mission is co-manifested with NASA's New Millennium Earth Orbiter-1 mission and is scheduled for late 1999 launch. NASA is providing launch vehicle, scalar helium magnetometer and GPS receivers. Argentines have various instruments such as multispectral scanner, and high resolution camera, etc. The spacecraft and the instruments completed CDR and are in various stages of manufacturing and testing. Spacecraft thermal and structural models were tested and qualified in 1998. The magnetic mapping payload has been calibrated as well. The main focus in 1999 is to finish the fabrication, integration and test of the spacecraft and payloads. The mission will be in operation in the year 2000.

The TOMS flight model 5 has been completed, is in storage, and was scheduled to fly as a cooperative mission with Russia in late 2000. However, Russia has delayed this mission until the year 2002 or later due to funding problems. Presently, the Agency is in the process of exploring other options.

BASIS OF FY 2000 FUNDING REQUIREMENT

APPLIED RESEARCH AND DATA ANALYSIS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Earth Science Program Science	303,800	323,700	337,300
Operations, Data Retrieval, and Storage	69,600	76,900	82,900
Total	373,400	400,600	420,200

PROGRAM GOALS

The goal of applied research and data analysis is to advance our understanding of the global climate environment, the vulnerability of the environment to human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

STRATEGY FOR ACHIEVING GOALS

The applied research and data analysis program is divided into two components: Earth science and Earth science operations, data retrieval, and storage. The activities under Earth science program science include research and analysis, EOS science, airborne science and applications, the purchase and management of scientific data, commercial remote sensing and Uncrewed Aerial Vehicle (UAV) science project. Operations, data retrieval and storage consists of several independent activities responsible for the operation of currently functioning spacecraft and flight instruments, high performance computing and communications, and the provision of computing infrastructure. Each of the major components of applied research and data analysis has its own set of goals, strategies for achieving goals, performance measures, and accomplishments and plans.

BASIS OF FY 2000 FUNDING REQUIREMENT

EARTH SCIENCE PROGRAM SCIENCE

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Research and analysis	169,400	171,000	182,100
EOS science	41,400	46,400	60,600
Mission science teams and guest investigators	45,900	48,100	38,800
Airborne science and applications	20,700	18,100	21,400
Uncrewed aerial vehicles (UAV)	1,900	2,000	4,000
Advanced geostationary studies	3,000	---	---
Commercial remote sensing	21,500	38,100	30,400
Total	303,800	323,700	337,300

PROGRAM GOALS

The goal for the Earth science research program is to contribute to the integration of the Earth and environmental sciences into an interdisciplinary scientific understanding of the Earth system and the effects of human-kind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes that pose risks to society. The science program also provides the analysis and integration of critical data and models needed for national and international assessments. An objective of current planning is to achieve the most essential, long-term objectives of EOS and to increase effort on science with near-term payoff, within a sustainable level of funding. The observational program will become resilient, better, and cheaper in the future by (1) taking advantage of the experience being gained in preparation of the first round of EOS flight missions to reduce observing requirements in the future and to simplify the design of instruments for more cost-effective continued operation, (2) finding alternative means to carry out some of the essential measurements at the same level of quality through cooperation with other agencies and nations, and (3) infusing new ideas and technologies into the EOS program through small satellite missions that have lower infrastructure and flight costs.

STRATEGY FOR ACHIEVING GOALS

The Research and Analysis (R&A) science project is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the USGCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change Research, and the various boards and committees at the National Academy of Science. The Research and Analysis consists of five priority areas: Land Use/Land Cover, Short-term Climate Change, Long-term Climate Change, Natural Hazards, and Atmospheric Ozone.

The Science strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural factors of change (e.g. pollution, climate variability, deforestation). Viewing the Earth from space is essential to comprehending the cumulative influence of human activities on its natural resource base. An important priority is to provide accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources. Observations from space are the only source of objective information on the human use of land in a time of rapid land use development. A related priority is to improve understanding and prediction of transient climate variation, such as El Niño anomalies. Reducing uncertainties in climate predictions a season or a year in advance would dramatically improve agriculture and energy utilization planning. Natural hazards research is exploring the use of remote sensing observations for mitigation of drought and flood consequences. There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like El Niño events. Special attention is being given to measuring and modeling the effects of relative forces, like clouds, aerosols and greenhouse gases in long-term climate change, in order to improve our assessments of climate trends on time scales of decades to centuries. A continuing priority is to understand the causes and consequences of changes in atmospheric ozone. Emphasis is now being placed on the changing composition of the lower atmosphere, which is sensitive to the unprecedented increase of pollutant emissions in rapidly developing regions throughout the world.

EOS science consists of focused research projects to analyze specific Earth science data sets and interdisciplinary investigations geared for a broader probe into Earth science system functions. The former is needed to control quality of data produced by interdisciplinary instrument computing facilities and the latter for bridging disciplinary boundaries. Both types of efforts are being supplemented by graduate student participation in the EOS science fellowship project.

The objectives of the mission science team/guest investigators are to analyze data sets from operational spacecraft that support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology.

The airborne science project funds operations of two ER-2s and one DC-8 aircraft. The project funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specially modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to spaceflight. The instrumented aircraft provide remote sensing and *in situ* measurements for many Earth science research and analysis field campaigns, including stratospheric ozone, tropospheric chemistry, and ecological studies throughout the world. The ER-2 aircraft, in particular, are unique in that they are the highest flying subsonic civilian research aircraft and were key in collecting *in situ* data for our understanding of ozone depletion and stratospheric transport mechanisms. One of these provided support and observations, including overflights of hurricane *Georges*, for an interagency experiment designed to improve our capability to predict hurricane landfall and intensity. The DC-8 aircraft provides a unique "flying laboratory" facility for a broad range of disciplines in atmospheric sciences.

The Uncrewed Aerial Vehicle (UAV) science project will augment the Earth science airborne project. Initially it will make *in situ* and remote sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation.

The Commercial Remote Sensing Program (CRSP) funds cooperative efforts with industrial, university, and state and local government partners aimed at enabling development of a viable commercial remote sensing industry. The cooperative effort will work to apply space-based data and instrument technology in the development of usable, customer-defined information products. Industry and others will make significant co-investments, funding or in-kind contributions to the co-developed projects at about an equal level with NASA. NASA and industry will work in a "joint discovery" mode to identify requirements for advance remote sensing observations/measurements, e.g., hyperspectral and SAR data that respond to and help satisfy future commercial market demand.

SCHEDULE AND OUTPUTS

The scientific issues of concern to Earth science are among the most complex and policy relevant of any major scientific research program. The results of Earth science program science are critical to the development of sound U. S. and global environmental policy, necessary for long-term sustainable development. Each of the science theme areas discussed in the accomplishments and plans section describe performance targets to ensure that the goal and objectives of the Earth science program science are met. A summary schedule and outputs relating to management, business practices, and bases for comparisons applicable to the whole Earth science program are in the table below.

	FY 1998 Actual	FY 1999 Estimate	FY 2000 Estimate
Number of principal investigators	1,075	1,100	1,175
Number of research tasks under way	1,500	1,525	1,600
Average duration of research tasks	3 years	3 years	3 years
Number of science solicitations released	19	21	22
Number proposals received	928	975	1,025
Number of proposals rated very good to excellent	498	525	550
Number of proposals selected	343	355	360
Time to process proposal (selection through obligation)	60 days	45 days	30 days
Number of days until funding is released	Simultaneously with award	Same	Same
Percent of R & A funding obligated:			
Current Budget Authority:	81%	87%	100%
Prior Budget Authority:	100%	100%	100%
Percent of program reviewed by science peers	95%	95%	95%

ACCOMPLISHMENTS AND PLANS

Research and analysis and EOS Science

In FY 1998, continuing into FY 1999 and FY 2000, the following are significant accomplishments in the areas of Land Cover/Land Use, Short-Term Climate Events, Long-Term Climate System Variability, Natural Hazards, and Atmospheric Ozone, EOS Science and Applications, and Education and Outreach

Land Cover/Land Use

The ESE will provide some of the underlying science to permit assessments of the current distribution of land-cover and land-use. It will examine the changes that have taken place in the last several decades, their impact on bio-geochemical cycling, biophysical processes, bio-diversity, trace gas and particulate fluxes, and coastal zone conditions. In addition, the likely impacts of future land-cover change will be assessed.

In FY 1998, NASA led an interagency effort to establish a web-site for Fire Monitoring by Satellite at http://modarch.gsfc.nasa.gov/fire_atlas/fires.html. Fire is one of the major disturbances of ecological systems around the world. Satellite observations of fire occurrence provide a systematic means of establishing baseline data and monitoring changes in fire occurrence and extent.

Satellite data analyses were published which showed a time-lag in the response of terrestrial ecosystems to climate variability. The response of ecosystems to climate variability influences the degree to which the biosphere is a net source or sink of carbon. The existence of time lags in the response is a critical feature of understanding how land-cover and land-use change might affect atmospheric composition.

The ESE produced a historical data set of key climate variables for the U. S. for the last 100 years and produced climate scenario data for the next 100 years for use in model inter-comparison studies and the U. S. National Assessment on the Potential Consequences of Climate Variability and Change. These historical data sets have a wide variety of uses in ecosystem modeling. The future climate scenarios provide the raw material for understanding what the potential climate impacts in the U. S. might be.

On December 10, 1998, the NASA Administrator and the President of the Central American Commission on the Environment and Development (CCAD) signed a Memorandum of Understanding (MOU) establishing cooperation between CCAD and NASA in support of the Mesoamerican Biological Corridor. The membership of CCAD consists of the Governments of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama; and all have agreed to work together within the CCAD framework to promote the sustainable development of the entire Central American region. In 1997 the Presidents of the seven Central American countries specifically endorsed the concept of a Mesoamerican Biological Corridor, running throughout the Central American isthmus, with a goal of integrating conservation and the sustainable use of the region's biodiversity.

Under the terms of the MOU, NASA (including the Marshall Space Flight Center, Jet Propulsion Laboratory, and other NASA-funded investigators) and Central American researchers will use satellite data to develop maps classifying the land cover of the Central American isthmus according to: life zones, land-use types, geological structure, hydrology, and other factors. NASA will also support the development of CCAD's environmental data and information system by making available optical, radar, and topographic remote-sensing data to CCAD. The MOU will initiate a new partnership between NASA and the countries of Central America and demonstrate the utility of NASA Earth science data and information for both biodiversity conservation and the planning of sustainable development.

The first year of near-daily global ocean color data from SeaWiFS was completed in September 1998. Weekly maps of surface-ocean chlorophyll distributions reveal dynamic seasonal patterns in primary production during the 1997-98 El Niño. The time series will be used to understand and predict the response of marine ecosystems to environmental change.

In FY 1998, ecological and biogeochemical cycling research on the effects of tropical forest conversion were initiated under the Brazil-led Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). Remote sensing studies in collaboration with the Brazilian National Institute for Space Research have documented the amounts and rates of deforestation in the 1990's and will continue with LBA. Mosaics of JERS-1 satellite radar images for the entire Amazon region have been produced in collaboration with Japan for both the peak wet and dry seasons, allowing an analysis of seasonally inundated forest areas. Field observations in Brazil and other Amazonian countries of carbon stores and fluxes, trace gas fluxes, nutrients in soils and vegetation, and land use practices and impacts will begin in 1999 and continue through 2002.

In FY 1999, we will begin to refresh the global archive of 30-meter land imagery from Landsat 7, three to four times per year. From the instruments on the EOS AM-1 spacecraft, and through the EOSDIS, we will begin collecting near-daily global measurements of the terrestrial biosphere. This is an index of terrestrial photosynthetic processes from which calculations of carbon uptake are made. In addition, we will collect near-daily global measurements of ocean color. This will provide an index of ocean productivity from which calculations of ocean update of carbon are made.

In FY 2000, NASA contributions to the First National Assessment of the Potential Consequences of Climate Variability and Change will be completed. These will include production of the climate scenario information, support of the National Synthesis, several of the U. S. regional analyses, and supporting research for several U. S. studies. We will participate in the Southern Regional Science Initiative-2000 (SAFARI-2000) regional international assessment in South Africa. This assessment will quantify the effects of climate variability and management practices on the environment.

Near-real time fire monitoring and impact assessment based on Landsat and EOS inventory and process monitoring will provide an observational foundation for monitoring changes in ecosystem productivity and disturbance. The ocean color time series with 60% global ocean coverage every four days will continue.

Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) will merge MODIS ocean color data into the global ocean color time series that began with Ocean Color Temperature Sensor (OCTS) and SeaWifs. Multi-year time series of ocean color data will be used to understand and predict the response of marine ecosystems to climate change.

We **will** continue the development of global land cover/use change data set based on Landsat and EOS instruments, at seasonal refresh rate. We will also continue to collect near-daily global measurements of the terrestrial biosphere from instruments on AM- 1.

Short-Term Climate Events (Seasonal-to-Interannual Climate Variability)

ESE research focuses on observing, understanding, and predicting climate variations that occur on time scales of seasons to a few years. This effort is important because variations in the upper ocean circulation and ocean surface temperatures, ocean color, sea ice, atmospheric circulation including the hydrologic cycle. atmospheric turbidity, and land surface conditions such as soil moisture and snow cover are hypothesized to be mutually interactive and to generate significant variations of climate on seasonal-to-interannual time scales. both globally and in specific regions.

Airborne measurements made in the smoke clouds evolving from biomass burning in Brazil have yielded optical parameters that permit an improved assessment of the effects of smoke on Earth's radiation balance. These measurements were made in NASA's Smoke Clouds and Radiation experiment in Brazil (SCAR-B). Biomass burning of the Brazilian Cerrado (savanna) and tropical rain forest regions, contributes an estimated 25% of the global production of greenhouse gases and particulates. SCAR-B resulted in a significant reappraisal of estimates of global radiation forcing of aerosols from biomass burning (-0.8W m-2 to -0.25 W m-2) and a factor of two reduction in uncertainty.

Theoretical analysis and aircraft measurements demonstrated that signals from Global Positioning System satellites reflected from the ocean may have numerous applications (e.g. altimetry, wind estimation. and ionospheric delay corrects for single frequency radar altimetry). Preliminary analysis of Space Shuttle data indicates that these reflected signals will be observable at orbital altitudes. With further confirmation and technical development, this represents a method of collecting information about the sea surface with substantially better temporal coverage and lower cost than other technologies.

In FY 1999, we will begin the second of a three-year sequence of instantaneous measurements of rainfall rates and monthly accumulations in the global tropics. This will be the first-ever measurement of global tropical rainfall. Current uncertainty in global tropical rainfall estimates is 50 percent: **TRMM** data will reduce this uncertainty to 10 percent, an 80 percent improvement.

We will provide 25 km resolution wind and direction measurements over at least 90 percent of the ice-free global oceans every two days. This represents a resolution increase of a factor of two, and a 15 percent increase in coverage over previous measurements.

In FY 2000, efforts will focus on the development/improvement of methods to couple state-of-art land surface and sea ice models to a global coupled ocean-atmosphere model and use this to predict the regional climatic consequences of El Niño or La Nina occurrence in the tropical Pacific. The ultimate goal is to develop a capability to significantly improve the prediction of seasonal-to-interannual climate variations and their regional climate consequences. The main focus is on North America. Measurements of the production and radiative properties of aerosols produced by biomass burning in Africa will be made as part of an international field experiment, the Southern African Regional Science Initiative-2000 (SAFARI-2000). The information obtained from this mission will assist in the interpretation of aerosol measurements made by instruments on NASA's EOS-AM spacecraft being launched in 1999. It is estimated that biomass burning in Africa contributes about one half of the global atmospheric aerosols.

The launch of NASA-CNES Jason-1 satellite mission will occur in FY 2000. This follow-on to TOPEX/Poseidon aims to achieve a factor of 4 improvement in accuracy in measuring ocean basin-scale sea level variability. This capability is one order of magnitude better than that specified for TOPEX/Poseidon.

Long-Term Climate System Variability

NASA contributes to broader national and international efforts to understand the causes and impacts of long-term (decades-to-centuries) variations in the climate system. Long-term climate variability encompasses changes of regional-to-global scale climate, both natural and human-induced, that occur over periods longer than a few years.

The Earth's weather and climate are driven by the transport of energy from the equator to the poles. Clouds modify the radiation budget of the earth at all latitudes, however, they can only form in the Arctic when breaks in the ice allow increased humidity and when pollution from lower latitudes provide nuclei on which to form. The NASA Arctic Cloud Experiment, performed in concert with surface observations provided through close coordination with the NSF sponsored Surface Heat Budget of the Arctic Ocean (SHEBA) project and the DOE sponsored Atmospheric Radiation Measurement (ARM) project, has provided detailed measurements of these subtle yet climatologically important processes. Results will also be used for the development and test of remote sensing algorithms for the EOS-AM1 MODIS instrument.

An ongoing project addressing the mass balance of the Greenland ice sheet by coordinated analysis of satellite, airborne, and *in situ* measurements indicates a warming trend since 1978. Increases can be found in the area of summer melting at lower elevations, but a more confused picture at higher elevations, with some areas thickening and some thinning. Results from repeated airborne laser surveys in 1998 and 1999, after a 5-year time interval, should help to clarify this picture.

There is increasing evidence that predictions of extreme weather events can be improved by understanding their links to interannual climate phenomena like the El Niño events. In FY 1999, through the AM-1 instruments, we will begin conducting daily observations of cloud properties such as extent, height, optical thickness, and particle size. We will map aerosol formation, distribution and sinks over the land and oceans. In addition, we will achieve a substantial reduction in the uncertainty in components of the Earth's radiation balance (e.g. improved angular models leading to an estimated error reduction in regional-scale monthly-average net radiation of about 50%).

Efforts in FY 2000 include analysis of the CERES measurements to achieve a further reduction in the uncertainty in the determination of top-of-the-atmosphere radiative fluxes through the integration of measurements provided by the CERES instruments on TRMM and EOS AM-1.

The first detailed estimates of thickening/thinning rates for all the major ice-drainage basins of the Greenland ice sheet, derived from repeated airborne laser-altimetry surveys will be published. These measurements also represent a baseline data set for comparison with early measurements by the Geoscience Laser Altimeter System (GLAS), to be launched in July 2001. The airborne project for mapping of layers within the Greenland ice sheet to decipher the impact of past climate variation on polar regions will be initiated.

Natural Hazards

The long-standing Earth science research program in fundamental solid Earth science explored issues such as tectonic motions, earthquakes, and volcanic eruptions. Results of this, and other relevant projects are developed and applied to the mitigation and management of natural disasters, working together with practitioners at the international, federal, state and local levels.

Through the development of technologies designed to observe and understand the Earth, the ESE possesses an inventory of tools which can be developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

In FY 1998, space-borne radar demonstrated the ability to monitor the surface deformation of a volcano from space. The volcano, Fernandia, in the Galapagos Islands, showed almost a meter of uplift on one of its flanks, evidence of subsurface movement of magma. This is an important element needed to provide warnings of eruptions.

In addition, a space-based method for monitoring volcanic gases for the volcano Popocateptyl in Mexico using the Earth TOMS during experiments in the low orbit mission phase was demonstrated. A 50% improvement in sensitivity monitoring gases was demonstrated in this orbit, making it possible to detect very small amounts of sulfur dioxide, which will aid in the development of an eruption warning system.

NASA's space geodetic measurement systems continued to improve to supply a mission-critical reference frame for satellites measuring global sea level change, ice sheet volume, and crustal motion. One system, very long baseline interferometry (VLBI), showed that it could also contribute to climate studies by detecting El Niño-related atmospheric influences on the Earth's speed of rotation.

In FY 1999, the NASA radar, flown in SIR-C, will be used by the DoD to create the first digital topographic map of 80 percent of the Earth's land surface. No ESE funds will be used for this mission known as the Shuttle Radar Topography Mission (SRTM). In addition, we will use GPS array in Southern California to monitor crustal deformation on a daily basis with centimeter precision and initiate installation of the next 100 stations. With GPS receivers in low earth orbit, we will test improved algorithms for sounding the atmosphere with the occulted GPS signal.

Research in FY 2000 will continue to develop models to use time-varying gravity observations, for the first time from space (in conjunction with the GRACE Mission) to estimate water storage changes to provide data to hydrologists on water mass expansion, flood impacts and climate variations. Demonstration of the utility of space-borne data for improved, faster and less costly flood plain mapping, an effort with Federal Emergency Management Agency will occur in FY 2000. We will use Southern California GPS array data to understand the connection between crustal movements and seismic risk to provide measures of earthquake vulnerability for disaster mitigation. An automatic volcano cloud/ash detection algorithm employing EOS data sets for use by the FAA will be developed. We will obtain, process and distribute imagery of current flooding for broad use in flood damage assessment and assessment of accuracy of flood plain maps comparing current flood insurance maps..

(

Atmospheric Ozone

NASA maintains an extensive research project related to atmospheric ozone in order to provide high quality scientific data on both the troposphere and stratosphere to the scientific community and to policy-makers who use such information in setting environmental policy.

In FY 1998, measurements of surface concentrations of chlorofluorocarbons (CFCs) and their replacements, halons, and other chemicals regulated under the Montreal Protocol and its Amendments showed a decreasing burden of regulated ozone destroying chemicals, and increasing abundance of replacement compounds less destructive to ozone in the lower atmosphere. These results confirm the efficacy of the Protocol which, if adhered to by the world's nations, will lead to recovery of the ozone layer sometime in the coming century. Satellite data have shown that the growth rate in the concentrations of the halogen-containing species formed in the stratosphere from the breakdown of CFCs and halons has begun to decrease, and continued observations should show stratospheric chlorine reaching its peak near the turn of the century.

Analysis of data made from a combined aircraft/balloon campaign based in Fairbanks, Alaska provided unprecedented detail about the annual decrease in summertime ozone levels in the high latitude northern stratosphere. These measurements showed that the net ozone decrease in these regions near the summer solstice reached -16% per month. These data are proving very useful in the critical testing of the computational models used to simulate the ozone distribution in the current and future stratosphere.

Detailed study of measurements made as part of two tropospheric aircraft experiments and new photochemical model results have provided clear confirmation of the predominant role of in situ photochemistry (especially that associated with oxides of nitrogen) as the source of most ozone in the free troposphere. The role of downward transport of ozone from the stratosphere into the troposphere has been much better understood, including its seasonal and latitudinal contribution to tropospheric ozone amounts. For the first time extensive measurements of the important OH molecule in the lower troposphere have been reported together with extensive measurements on the processes that produce and destroy it, allowing for quantitative tests of ideas about its formation and destruction at these levels. Major new insights have also been gained on sulfur chemistry through the first measurements of several major sulfur compounds in the free troposphere. The formation of new sulfate particles has been observed in the remote troposphere for the first time shed new light on the way in which atmospheric pollutants are oxidized into radiatively important aerosols.

Trend studies of ozone distributions carried out over the past ~ 20 years using ground-, balloon-, and space-based observations have shown excellent agreement on loss rates of ozone in the upper stratosphere, which are consistent with computational models. Improved estimates of ozone loss in the difficult-to-measure lower stratosphere have been developed through refinements to the balloon-borne ozonesonde and satellite databases. Approximate downward trends in the 1980-1996 time frame are between 7.5% per decade at 15 km and 40 km and 2.5% per decade at 30 km.

Model calculations suggest important coupling between climate change and ozone depletion. Computer model calculations carried out for an atmosphere with increasing carbon dioxide amounts suggest that there can be complex interactions between climate and chemistry that could lead to enhanced ozone depletion in the Arctic. If the polar vortex were to become more persistent, as the model calculations suggest, there could be an increased chance for springtime ozone depletion in the northern hemisphere.

A continuing priority area will be the development of data sets suitable for long-term study of the evolution of atmospheric composition. A 20-year data set for total ozone will be constructed using data from the TOMS and SBUV/2 series of instruments. Long-term data sets for other TOMS products (surface UV flux, tropospheric aerosol distribution, tropical tropospheric ozone column) will also be constructed from TOMS data. A revised long-term data set for the vertical profile of ozone and aerosols will be obtained from the SAGE II instrument covering the first 14 years of its operation (1984-1998). Long-term data on the distributions of a variety of ozone-affecting trace chemicals in the stratosphere and upper troposphere, as well as of the solar ultraviolet radiation responsible for driving atmospheric photochemistry, will be provided by the Upper Atmosphere Research Satellite, which is now in its eighth year of operation.

The first initiation of the full Southern Hemisphere Additional Ozonesonde network to obtain the first ever climatology of upper tropospheric ozone in the tropics will be completed. This will involve the coordination of measurements made by a number of nations in the tropics and southern subtropics, and assembly into a database that can be easily used by the atmospheric science community.

The second Pacific Exploratory Mission in the tropics, PEM-Tropics-B, a focused airborne campaign (with an associated ground component), will be carried out in FY 1999 in order to further our knowledge of the distribution of ozone in the troposphere over the tropical Pacific. The detailed measurements of ozone and its sources provided by this mission, will provide additional seasonal and temporal information from that obtained during the first PEM-Tropics mission, and will make use of an improved in situ sampling payload. Analysis and interpretation of data will be carried out in FY 2000, while further improvements to the payload will be made to allow for an improved instrument complement to be used in another Pacific-based tropospheric chemistry mission planned for 2001.

We will continue to monitor and assess the impact of the Montreal Protocol and the Framework Convention on Climate Change with globally-distributed measurements of the surface level concentrations of long-lived industrially-produced trace gases and other biogenically-produced gases such as methane and nitrous oxide.

In addition, we will complete acquisition of first ever-global climatology of vertical profiles of carbon monoxide (CO) to improve knowledge of its surface sources, photochemical destruction, and how it is transported by tropospheric wind systems (based on MOPITT data from AM-1). Detailed validation of the MOPITT data product will be carried out with a variety of surface- and airborne-based in situ sampling, as well as ground-based optical remote sensing instruments.

Efforts in FY 2000 will implement the SAGE III Ozone Loss and Validation Experiment (SOLVE). Measurements will be made during the timeframe of October 1999 - March 2000 in the Arctic and high-latitude region in winter using the NASA DC-8 and ER-2 aircraft, as well as balloon platforms. The mission will also acquire correlative data needed to validate the SAGE III satellite measurements that will be used to quantitatively assess high-latitude ozone loss.

We will continue to monitor and assess the impact of the Montreal Protocol and the Framework Convention on Climate Change with globally-distributed measurements of the surface level concentrations of long-lived industrially-produced trace gases and other biogenically-produced gases such as methane and nitrous oxide. In addition, we will complete acquisition of first ever-global climatology of vertical profiles of carbon monoxide (CO) to improve knowledge of its surface sources, photochemical destruction, and how it is transported by tropospheric wind systems (based on MOPITT data from AM-1). Detailed validation of the MOPITT data product will be carried out with a variety of surface- and airborne-based in situ sampling, as well as ground-based optical remote sensing instruments.

Applications, Education and Outreach

The goal of the Earth Science Applications Research Program (ESARP) is to enable the productive use of ESE science and technology in the public and private sectors in response to user needs. To achieve the goal, the ESARP works with partners to extend Earth Science results, data and technology to a broad range of users. In FY 1998, ESARP competitively selected twelve Type 3 Earth Science Information Partners (ESIPs) out of 65 proposals and initiated implementation of the Cooperative Agreements for a project duration of 5 years. The ESIPs will be assisting to establish the EOSDIS Prototype Federation, and will also begin extending ESE science results, data and technology to the user community for routine decision-making. During FY 1998, the results consisted of the formal establishment of the Federation including developing a Federation Experiment Design Process, establishing a process of governance, implementing key governing committees, developing a secretariat, and formulating an evaluation design for the Federation in order to be able compare the coordinated Federation results in the future against the current EOSDIS design. In FY 1999, the Type 3 ESIPs will focus on applications development and interactions with the potential broader user community. Examples of partner activities include NBC Channel 4 in Washington, D.C. (weather and news) which is developing (system specification completed) an integrated News and Weather Visualization System for use within NBC owned and operated television stations. The system is based on using public and private remotely sensed data that would be used to generate products that can be used on-air. Another example is the New Mexico Earth Data Analysis Center (EDAC) which is working with state, regional and local problems. To date, they have worked with the New Mexico Land Office and Middle Rio Grande Council of Governments to develop baseline GIS databases and remote sensing applications for land economics and regional hydrology, and have developed a multimedia image sampler to introduce the broader user community to the types of data available for operation and commercial applications. A third partner, Reading Information Technology, Inc. is working to use remotely sensing data as part of a computerized decision support system to assist in determining sea conditions that would increase shipping cost and determine "optimized" ship routing. To-date, they have established the research partnership with Canadian Steamship Lines (CSL) and have successfully established GIS software on both ship and shore including the vessels' GPS navigation. Future work is designed to create a system which automatically downloads the remotely sensed data into the software and provides a the means to deliver any need course or speed deviation to the vessel's captain without human intervention. Another partner, the Bay Area Shared Information Consortium (BASIC) is working with the San Francisco Bay Area Governments and the wine industry to develop a multi-use, data sharing information system. To-date, they have worked with the City of San Jose, Santa Clara Basin Watershed Management to understand their data needs and initiate development of application in watershed management, nitrate filtration, and water conservation.

In addition, ESE participated in over 30 partnerships with public and private user organizations to apply ESE science results, technology, data and expertise to routine decision-making such as developing biweekly "Green Reports" with the University of Kansas for assessing crop/vegetation condition, growth progress and change. These reports are distributed to 6,000 subscribers including farmers, agribusiness's, brokers and state and local government agencies.

In FY 1999, ESARP selected nine proposals which have been integrated into seven Regional Earth science Applications Centers (RESACs) designed to apply remote sensing and related technologies to problems of regional significance and conduct region specific assessments. The RESACs are addressing problems such as forest growth and health, precision agriculture, land cover and land use mapping and inventory, water resources management, rangeland quality assessment, fire hazard management, integrated watershed and coastal management, assessment of long-term agricultural productivity and sustainability. The outcome of the RESACs will be an enhanced knowledge of potential regional consequences of climate change and variability by regional stakeholders such as state and local governments and private industry. This knowledge will lead to practical advances in the management of regional resources. These advances will be accomplished through regional applications research projects resulting in improved inventories of forest growth, more accurate mapping of land use and land cover, improved assessments of rangeland quality and long-term agricultural productivity, integrated regional management of hydrologic and coastal resources, and reduced risk of loss due to fire resulting in millions of dollars of savings to society. At least one RESAC will become self-sustaining and at least 3 advanced applications and remote sensing products will become operationally used.

In addition, ESARP will initiate jointly with the USDA: (1) at least 8 new projects in the areas of vegetation mapping and monitoring, risk and damage assessment; and resource management and precision agriculture; and (2) 2 pilot projects leveraging the existing successful Land Grant and Space Grant networks into a cooperative NASA ESE/USDA Cooperative Extension Service Strategic Alliance in Geospatial Information Technology (i.e., remote sensing, GIS, GPS). Both of these activities will extend ESE's science results and push the existing applications science envelope forward in partnership with USDA. The Alliance will use remote sensing, GIS, GPS and other geospatial technologies to improve the benefits of traditional university extension activities for the Nation's farmers. The outcome will result in the development and validation of at least two new data products for routine decision-making by user organizations in the area of improved knowledge of capability and suitability of agricultural lands and increasingly efficient site specific agricultural techniques. The solicitation for cooperative Applications Research projects with state and local governments will also be completed and released.

In FY 2000, NASA contributions to the first USGCRP National Assessment of the Potential Consequences of Climate Variability and Change will be completed, with a report to Congress planned for January 2000. These will include production of the climate scenario information, support of the National Synthesis, several of the U. S. regional analyses, and supporting research for several U. S. studies. We will conduct the first regional international assessment in South Africa. This assessment will quantify the effects of climate variability and management practices on the environment. In addition, NASA will sponsor two regional assessment studies of environmental variations and natural resources vulnerability.

In FY 2000, ESARP will initiate at least 7 cooperative agreement with state and local governments in areas such as land use planning, land capability analysis, critical areas management, and water resources management resulting from the solicitation. These cooperative agreements will result in improved decision support systems in areas of priority needs defined by state and local governments including: land use and land cover inventory; land capability/suitability analysis; critical areas management; water resources management; forest inventory; site and route selection; and emergency preparedness. At least 2 new satellite remote sensing based applications will be developed in these applications areas as a result of these agreements.

In addition, based on the successful implementation of the pilot projects, the cooperative NASA/ESE USDA Cooperative Extension Strategic Alliance in Geospatial Information Technology will be expanded to at least an additional 5 states.

EOS science

In FY 1998, 52 new graduate student research grants (5% over goal) were awarded EOS Science Fellowship grants. In FY 1999, we will award 50 new graduate student research grants and 20 early career grants in Earth science. In FY 2000, we will award 50 new graduate student research grants and we will continue the 20 new U. S. early career grants in research/education in Earth science.

We will continue funding the original EOS interdisciplinary teams through FY 2000 and those selected with the NRAs in FY 1996 through FY 1999. Beginning in FY 2000 we will conduct a NRA for a new group of EOS Interdisciplinary scientist to fit with the new way of doing EOS missions.

Mission science teams and guest investigators

The mission science team/guest investigators funding provides for analyzing data from the UARS, TOPEX, Earth Radiation Budget Satellite (ERBS) and other spaceborne instruments such as Solar Backscatter Ultraviolet (SBUV/2), TOMS, and TRMM. The exploitation of UARS data still involves more than 100 investigators from the United States and many other countries, notably Canada, the United Kingdom, and France. Key TOMS and SBUV/2 participants include NOAA, Russia and Japan. Key ERBS users include a diverse set of institutions including NOAA (NOAA manifested Earth Radiation Budget Experiment (ERBE) sensors on NOAA-9 and -10 in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography. The TOPEX users include France (shared in development of the mission), Japan, Australia, the United Kingdom, the Netherlands, Germany, Norway, and South Africa as well as JPL, GSFC, Columbia University, the University of Hawaii, the University of Texas, the University of Colorado, Oregon State University, Ohio State University, and the Massachusetts Institute of Technology. SeaStar/SeaWIFS principal users include GSFC, the European community, Japan, Canada, and Australia and universities in Florida, Washington, California, Texas, Maryland, and Rhode Island. At present, the largest demand for ocean color data arises from the Joint Global Ocean Flux Study (JGOFS), an international program under the auspices of the Scientific Committee for Oceanographic Research (SCOR) and the International Geosphere-Biosphere Program (IGBP). NSCAT investigators include scientists from JPL, NOAA, and Japan (manifested the NSCAT for flight on their ADEOS-1 spacecraft), and universities in New York, Washington, Oregon, and Florida. TRMM is a joint mission with Japan to measure tropical precipitation from a low inclination orbit. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL, represent nations in almost every continent including Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

Airborne science and applications

In FY 1998, twelve major campaigns were flown, over 1100 flight hours. The campaigns produced science data for rainfall, land-cover/land-use and atmospheric chemistry. Six major campaigns are scheduled for 1999, over 1300 flight hours. The core NASA Earth science aircraft fleet is fully subscribed, therefore lease, or other acquisition method, will be used to fulfill the requirements which cannot be met by the core fleet. The campaigns will return scientific data on tropical rainfall, tropical land cover, arctic ice, Pacific atmospheric chemistry, as well as land-cover/land-use, soil moisture and salinity.

Uncrewed Aerial Vehicles (UAVs)

The Uncrewed Aerial Vehicle (UAV) science project will augment the Earth science airborne project. Initially it will make *in situ* and remote sensing measurements focused on atmospheric sciences. These UAVs will stay over a target for extended periods to measure detailed temporal changes, provide unique views of cloud structures and provide calibration and verification of Earth science satellite instrumentation.

Initial work in the UAV science was to develop and test a payload of instruments suitable for study of the radiation field in the upper troposphere and lower stratosphere as well as the relationship between atmospheric physical and chemical parameters and the radiation field. The centerpiece of this payload is a newly-constructed high resolution infrared and far infrared radiometer. The radiometer has been tested on the ER-2 and has been flown on the ER-2 together with several other instruments making measurements of atmospheric physical and chemical properties in order to provide enough data to test the retrieval algorithms used to interpret data from the radiometer. Both series of test flights were carried out from the Dryden Flight Research Center in California. In FY 1999 or early FY 2000, the plan is to fly the radiometer and a small number of other instruments on a UAV. The UAV must have sufficient flight heritage and instrument modifications will be necessary to mate with the selected UAV. For FY 2000 and beyond, a NRA will be issued soliciting concepts for UAV missions supporting the science and applications goals of the ESE.

Advanced geostationary studies

The Advanced Geosynchronous Study (AGS) effort has made significant progress in evaluating various new imaging, sounding, and lightning mapper instrument concept designs and technologies that could be applied to using geosynchronous orbit as a cost-effective vantage point for supporting Earth science research objectives as well as NOAA observational requirements. The study effort has also investigated technologies and concepts for advanced geosynchronous spacecraft and associated ground data processing and distribution techniques required to support the advanced instrumentation. All activities were closely coordinated between NASA and NOAA.

Commercial remote sensing

The goal of the Commercial Remote Sensing Program (CRSP) is to accelerate the development of a preeminent U.S. remote sensing industry and link Earth Science Enterprise scientists with the commercial remote sensing industry to develop mutually beneficial partnerships. To achieve this goal, the CRSP implements a variety of partnership programs that enable joint development of technology and applications with private companies, agencies, and educational centers. In FY 1998, the Commercial Remote Sensing Program (CRSP) sponsored over 25 joint projects with commercial firms in value added remote sensing product development. Approximately one third of these have begun new product development activities, and of the remainder, 10 trademark products have been introduced to the market. These companies report approximately $2 million in cumulative gross revenues and $20 million in capital investments in their companies which they attribute to their partnership with NASA. We established over 30 new agreements with private industry including: ESE Scientific Data Buy completed 10 phase 1 projects which resulted five phase 2 awards in September, 1998, negotiating 5 agreements for the Earth Observations Commercial Applications Program (EOCAP) SAR Data Initiative and 10 agreements for the EOCAP Hyperspectral Initiative. The Scientific Data Buy (SDB) is a pilot program developed to purchase remote sensing data from the private sector. This program is designed to advance Earth science research utilizing commercial data sources and to test a new way of acquiring science quality data. The EOCAP SAR Initiative seeks to determine the utility of advanced SAR applications. This program will also define commercially viable markets that radar technologies can address. The EOCAP Hyperspectral Initiative is designed to define the technology gaps that prohibit or impede the use of hyperspectral data in the U.S. industry and recommend solutions for filling those gaps. The final goal of this program is to have a sustainable and reliable commercial provider of spaceborne hyperspectral data.

In addition, the CRSP has extended their Affiliated Research Program (ARC) from four universities to nine. This allows CRSP to work with over 60 companies per year. Through short, well defined demonstration projects, these companies are examining the utility of remote sensing and geospatial technologies in providing solutions for their commercial customers. The Federal government's role in these activities is to perform fundamental research, advanced technology and applications development, validation of data and application performance to enable better management of Earth resources. Another outcome of these efforts is the exposure of graduate students to real world challenges in their areas of remote sensing expertise better preparing them to enter the workforce.

In FY 1999, Commercial Remote Sensing will establish at least 75 commercial partnerships in value added remote sensing product development, an increase from 37 in FY 1997 and 70 in FY 1998. This will result in further penetration into markets that rely on geo-spatial information in the management of earth resources. In addition, we will establish at least 20 agreements with industry in support of other federal agency needs (e.g., Department of Transportation (DOT), U. S. Department of Agriculture (USDA)). For example, remote sensing technologies and their role in precision farming will be investigated in a joint USDA and NASA initiative beginning in the year 2000. The application of remote sensing technologies improve the yield and reduce the cost of agricultural production. Specifically these projects will examine the use of remote sensing and geo-spatial technologies to assess soil variability and variable rate applications of seeds, nutrients, pesticides and herbicides to a variety of crops. With the DOT, remote sensing technologies are also being applied to the planning of transportation corridors and the analysis of traffic flow and infrastructure development. The state level departments of transportation will be enlisted to help validate these technologies. In FY 2000, the CRSP will focus EOCAP joint commercial applications research to develop 20 new-market commercial products. These products will provide the basis for commercial services to continue to support the ongoing geo-spatial needs of the Agricultural and Transportation agencies and the respective markets they represent.

Three commercial sources of science data (from data buy) for global change research and applications will be established. The science data will be made available to Earth science researchers for their investigations under terms consistent with the negotiated data licensing agreements with the commercial data providers. Two new validated commercial information products will be developed as a result of verification and validation partnerships with industry to increase customer confidence and product understanding. These products will provide a validated baseline of the new commercial remote sensing satellite and airborne offerings that will be available in the near future.

BASIS OF FY 2000 FUNDING REQUIREMENT

OPERATIONS, DATA RETRIEVAL AND STORAGE

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Mission operations	47,000	56,300	54,600
(Upper Atmosphere Research Satellite)	(4,800)	(8,200)	(6,700)
(Total Ozone Mapping Spectrometer)	(2,700)	(2,700)	(3,000)
(Ocean Topography Experiment)	(10,700)	(11,000)	(11,100)
(Tropical Rainfall Measuring Mission)	(10,600)	(10,900)	(11,000)
(Satellite Laser Ranging)	(5,700)	(5,700)	(5,000)
(Earth Science)	(12,500)	(17,800)	(17,800)
High Performance Computing And Communications- Earth And Space Sciences	18,300	14,500	21,900
Information systems	4,300	6,100	6,400
Total	69,600	76,900	82,900

PROGRAM GOALS

Operations, Data Retrieval and Storage (ODRS) provides the data and data products from EOS precursor missions, including the UARS, TOPEX, TOMS, NSCAT and TRMM, required to understand the total Earth system and the effects of humans on the global environment. The goals of the NASA High Performance Computing and Communications (HPCC) project are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the U. S. aeronautics, Earth science, and space science communities and to accelerate the implementation of a national information infrastructure.

STRATEGY FOR ACHIEVING GOALS

This project supports the observations and data management portion of Earth science activities. The project will achieve its goals through the following: mission operations, high performance computing and communications, and information systems. The data and data products from this project have or will migrate to the EOSDIS.

Mission Operations

The objectives of the mission operations program are to acquire, process, and archive long-term data sets and validated data products. These data sets support global climate change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology. Funding provides for operating spacecraft such as UARS, TOPEX, ERBS, TOMS, TRMM, and processing of acquired data. Key users of UARS data include NOAA, the Naval Research Laboratory, GSFC, JPL, Canada, the United Kingdom, and a number of universities including the University of Michigan, the Georgia Institute of Technology, the University of Washington, the State University of New York, and the University of Colorado. Key TOMS proponents include NOAA, Russia (manifested a TOMS on their Meteor 3 satellite launched in 1991), Japan (manifested a TOMS on their ADEOS satellite launched in 1996). Key ERBS users are a diverse set of institutions including NOAA (manifested ERBE sensors on NOAA-9 and -10 launched in the 1980's), GSFC, LaRC, the State University of New York, Oregon State University, and the Scripps Institution of Oceanography.

Key participants involved in the Alaska SAR Facility (ASF) include the European Space Agency (ERS-1 and -2), Japan (JERS-1), Canada (RADARSAT), GSFC, JPL, and the University of Alaska which hosts the ASF. Participants in the analysis of SIR-C/X-SAR data, in addition to JPL, represent nations on almost every continent and include: Italy, Saudi Arabia, China, Australia, France, Canada, Brazil, the United Kingdom, and Germany.

The Satellite Laser Ranging (SLR) System is NASA's contribution to a world-wide laser ranging network. In additional to providing extremely precise tracking for a number of spacecraft (including TOPEX and a host of international missions), the SLR network makes significant contributions to Earth science (such as precise measurements of the gravity field and the station's vertical position with respect to the Earth's center of mass).

The Optical Transient Detector (OTD) instrument has numerous customers for data including NASA, NOAA, USAF, Massachusetts Institute of Technology, Texas A&M, University of California at Los Angeles, Colorado State, and international requests for data from Chile; German Aerospace Center (DLR); University of Frankfurt, Germany; the Swiss Institute of Atmospheric Physics; South Africa; Mexico; Hungary; Tel Aviv University and Haifa University, Israel; the United Kingdom Meteorological Office; France; Potsdam Institute for Climate Impact Research, Germany; and China.

High Performance Computing and Communications (HPCC) - Earth and Space Sciences

The NASA HPCC program consists of five discipline-related integrated projects. These projects are Computational Aerosciences (CAS), managed by the Office of Aero-Space Technology; Earth and Space Sciences (ESS), managed by the Office of Earth science; Remote Exploration and Experimentation (REE), managed by the Office of Space Science, National Research and Education Network (NREN), managed by the Office of Aero-Space Technology, and Learning Technologies (LT). The LT project focuses on providing the technology base and applications to accelerate the implementation of the national information infrastructure and to communicate and distribute science and engineering materials to the education community.

The implementation of the NASA HPCC program is mainly through coordinated activities at NASA field centers. The ESS project, led by GSFC, will work in close partnership with industry, academia and government. The project used the NASA research announcement process to select ten principal investigator teams and twenty-one NASA/NSF sponsored Grand Challenge investigations and to implement them on advanced parallel computers. The LT project uses remote internet technologies developed by NASA and other federally funded agencies to expand the application outreach of its programs to traditionally unserved communities. The Internet is used as the primary means of providing access to and distribution of science and engineering data.

Information Systems

The Earth science information system project has been structured to provide a balanced system of high performance computers, mass storage systems, workstations, and appropriate network connectivity between researchers and components of the system. A major portion of the project funding supports operation of a supercomputing center (the NASA Center for Computational Sciences) at GSFC. A full range of computational services are provided to a community of approximately 1,400 users representing all disciplines of Earth and space sciences. Users of the supercomputer complex select representatives to an advisory committee who are integrally involved in strategic planning for the evolution of the complex. They provide feedback on user satisfaction with services provided and help establish priorities for service and capacity upgrades. Offsite NASA-sponsored users comprise 25% of the total. The project monitors and participates in advanced technology projects, such as the HPCC program and National Science Foundation's gigabit testbed programs. Project elements at GSFC and JPL are focused on providing early access to emerging technologies for the Earth and space science communities. The early access to new technology provides the project with the opportunity to influence vendors and system developers on issues unique to the Earth and space science researchers such as data intensive computation and algorithm development. Early access also prepares a subset of the research community to make changes in research methodology to exploit the new technologies and to champion promising technologies to their colleagues and peers.

SCHEDULE AND OUTPUTS

OPERATIONAL SPACECRAFT/INSTRUMENTS

Common to all missions:

Archive 95% of planned data acquisition

The primary criteria for success of an operational spacecraft is to obtain 95% of the planned data acquisition.

UARS
(launched September 1991) continuing operations

The spacecraft launched in September 1991 with an expected five-year mission life. It has gone well beyond the expected mission life providing data to support improvements monitoring the processes that control upper atmospheric structure and variability, the response of the upper atmosphere to natural and human-induced changes, and the role of the upper atmosphere in climate variability.

TOPEX/Poseidon (launched August 1992) continuing operations	The spacecraft launched in August 1992 with an expected three-year mission life. The extended mission was defined to be three additional years. It is now in the final year of this extended mission life.
ERBS/ERBE/SAGE II (launched Oct. 1984, December 1984 and September 1986) continuing operations	The ERBS spacecraft launched in October 1984. It has gone well beyond the expected mission life.
Alaska SAR Facility Missions: ERS-1 (launched 1991) JERS-1 (launched 1992) ERS-2 (launched 1995) RADARSAT (launched 1995) ADEOS (launched 1996)	The Alaska SAR Facility is a ground receiving station and data processing station with no "end of life" defined. It supports ERS-1, JERS-1, ERS-2, and RADARSAT. All of these are international missions. There are currently no unique metrics defined for ASF other than the common metric listed above.
OTD (launched 1995) continuing operations	This instrument was launched in 1995 as a six-month technology demonstration. It has far exceeded its designed mission life.
TOMS FM-3 (launched July 1996) continuing operations	The TOMS-EP spacecraft was launched in July 1996 with an expected five-year mission life. It is currently in its primary mission phase. The first global ozone image was produced and released September 13, 1996. Automated processing and distribution of science products began September 20, 1996 and Internet distribution started on October 7, 1996.
TRMM (Launched November 1997) continuing operations	The spacecraft launched in November 1997 with a three year mission life. All operations are nominal, except the CERES instrument is non-operational due to an anomaly with Data Acquisition Assembly Converter.
SeaStar / SeaWIFS / Ocean Color (Launched August 1997 continuing operations for data processing)	The spacecraft launched in August 1997. This is a data buy from Orbital and the operation of the spacecraft is an Orbital responsibility.

ACCOMPLISHMENTS AND PLANS

Data has been acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products for global and/or regional monitoring purposes from all operational spacecraft and instruments. The current emphasis on global modeling in support of policy decisions on such matters as the impact of deforestation, ozone depletion, and environmental quality worldwide has led to the acquisition and manipulation of unprecedented amounts of environmental data. The accompanying computational demand has led to a doubling of production computing capacity and quadrupling of mass storage capacity in the last two fiscal years. These added demands are being addressed in the agency's initiative to consolidate supercomputer-based information systems.

In the mission operations project, responsibility for assigned missions is assumed 30 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products.

User requirements will be met in 1999 and 2000 by continuing operations of on-orbit spacecraft and instruments including the UARS, TOPEX, and ERBS missions; and continuing receipt of ERS-1, JERS-1, and RADARSAT data at the Alaska SAR Facility. In addition, OTD, SeaStar/SeaWIFS, TOMS and TRMM. The NSCAT instrument, while no longer operational, is still undergoing levels of data processing.

The TRMM transitioned to routine operations in 1998. Data processing for the SAGE III instrument will begin in 1999.

The Earth science information systems project will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and JPL. Partnerships with industry and other federal agencies will be used to assure the presence of the project's requirements in the strategic planning of new computational technologies. Recently initiated cooperative agreements will allow the development of supercomputer applications 10 times faster than today, providing the computational studies necessary to mesh with NASA's observational and theoretical projects.

BASIS OF FY 2000 FUNDING REQUIREMENT

GLOBAL OBSERVATIONS TO BENEFIT THE ENVIRONMENT (GLOBE)

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Global Observations To Benefit The Environment..............	5,000	5,000	5,000

PROGRAM GOALS

The goal of the Global Observations to Benefit the Environment (GLOBE) program is to link scientific discovery with the education process in the study of the Earth as an integrated system. The objective is to bring school children, teachers, and scientists together to: (1) enhance environmental awareness of individuals throughout the world; (2) contribute to scientific understanding of the Earth; and (3) help all students reach higher levels of achievement in science and mathematics.

STRATEGY FOR ACHIEVING GOALS

The GLOBE program is an interagency activity led by NOAA in which NASA has a key role. It involves students (kindergarten through twelfth grade or equivalent) in schools throughout the world, their teachers and the research community. Participating schools are making core sets of GLOBE measurements using GLOBE instruments and procedures under the guidance of GLOBE-trained teachers. The results from all over the world are reported into a central data processing facility. The students then receive feedback and use GLOBE educational materials to understand the compiled results and do their own analyses of the data.

In order to meet the first objective of increasing international environmental awareness, the program has been designed to be international in scope, involving students, educators and researchers from all over the world. By using the Internet to link the schools together, a sharing of discoveries and analysis is encouraged that should result in awareness beyond just the local community.

The second objective to contribute to the scientific understanding of the Earth, is achievable due to the expansive data sets that result from long term, repeated measurements made in areas where data has in some cases been extrapolated in the past. To ensure the greatest possible accuracy of the data, international environmental scientists have been involved from the beginning of the program to select a set of significant scientific measurements that can be made by students and define the experimental procedures and data reporting protocols for each.

SCHEDULE AND OUTPUTS

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Revised	Plan
Number of Participating Schools	6,000	5,400	8,000	8,000	10,500

ACCOMPLISHMENTS AND PLANS

By the end of FY 1998, The GLOBE program continued its rapid growth across the United States, focusing on areas of special interest, including empowerment zones and rural areas. For teacher training, a compliment of train-the-trainer and franchise approaches was incorporated to meet the demand and resources which are applied from GLOBE's private sector partner. Schools participating in GLOBE increased to 5,400, a 26% increase from 4,300 in FY 1997. In addition, countries participating in GLOBE increased to 70, a 14% increase from 62 in FY 1997.

In FY 1999, GLOBE will conduct at least 300 workshops to train teachers in use of ESE education products. The number of schools participating in GLOBE will increase to 8,000, a 30% increase over FY 1998 and the number of participating countries will increase to 72, up from 70 in FY 1998.

During FY 2000, GLOBE will sponsor at least 300 workshops to train teachers of OES education products. The number of participating schools in GLOBE will increase from 8,000, in FY 1999, to 10,500. Also, the number of participating countries in GLOBE will increase from 72, in FY 1999, to 77.

BASIS OF FY 2000 FUNDING REQUIREMENT

LAUNCH SERVICES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Launch services	39,400	4,200	---

PROGRAM GOALS

The goal of the launch services within the Earth science project is to provide the flight projects with cost-effective, on-time Expendable Launch Vehicle (ELV) launch services.

STRATEGY FOR ACHIEVING GOALS

The launch services budget includes funding through FY 1999 to support EOS AM-1 and Landsat-7 mission support needed to maintain the capability for Earth science missions. Beginning in FY 1999 the mission support is consolidated with Space Science mission support and budgeted in Human Space Flight.

SCHEDULE AND OUTPUTS

EOS AM-1 — To be launched on an Atlas IIAS from Vandenberg AFB.
- Plan: June 1998
- Revised: July 1999

Landsat-7 — To be launched on a Delta II from Vandenberg AFB.
- Plan: December 1998
- Revised: April 1999

ACCOMPLISHMENTS AND PLANS

Funding will continue in support of the EOS AM-1, Landsat-7 launches in 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

CONSTRUCTION OF FACILITIES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Construction of Facilities..	---	1,500	1,000

For additional detail, refer to the Mission Support, Construction of Facility section.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Aeronautical research and technology	920,100	768,900	620,000	SAT 4.1-1
Advanced space transportation technology	417,100	429,600	254,000	SAT 4.2-1
Commercial technology programs	146,700	140,400	132,500	SAT 4.3-1
Total	1,483,900	1,338,900	1,006,500	

PROGRAM GOALS

NASA is responsible for addressing aeronautics and space priorities as outlined by the National Science and Technology Council in national aeronautics and space policies. The responsibility of industry and operational government agencies is to meet their near-term customer requirements through evolutionary advancements to their products. The Aero-Space Technology Enterprise's responsibility is to provide revolutionary advancements in science and technology that sustain global U.S. leadership in civil aeronautics and space. To meet this challenge, the Enterprise's objectives are grouped into three synergistic goal areas or "pillars": Global Civil Aviation, Revolutionary Technology Leaps and Access to Space. The objectives within these goals are framed in terms of final outcomes once NASA-developed technology is integrated with, and further developed by, its partners. The technologies associated with these goals and objectives are pre-competitive, long-term, high-risk research endeavors with high-payoff in terms of market growth, safety, low acquisition cost, consumer affordability and cleaner environment. The goals and objectives are ambitions and stretch the boundaries of our current knowledge and capabilities. Given available funding, NASA recognizes that they are not all achievable within the stated timeframes. As a result, priorities were established and resources realigned to enable achievement of the highest payoff objectives on a timely basis. Progress will be made toward the remaining objectives, but at a slower rate, by concentrating on fundamental research.

Pillar One: Global Civil Aviation

Global civil aviation provides the backbone for global transportation, the very basis of global economic and cultural exchange and integration. It is a large and growing market that the U.S. has traditionally led. Projected growth approaches a tripling of air traffic over the next twenty years. Moreover, examination of various alternative futures suggests that there is also the potential for greater dispersion of operations, very high value for flexible, ultra-reliable operations, and increasing utilization of aircraft with unique operational characteristics.

A need exists to address the fundamental, systemic issues for the aviation system to ensure the continued growth and development appropriate to the needs of the national and global economies. These systemic issues—safety, capacity, environmental compatibility, and affordability cut across markets including large subsonic civil transports, air cargo, commuter and general aviation, and rotorcraft. To ensure these systemic issues do not become constraints, dramatic improvements should be aggressively pursued. Therefore, the Enterprise has worked with its partners to identify five enabling technology objectives to sustain the United States aeronautics leadership by providing high-risk technology that cuts across all markets in Global Civil Aviation:

- Reduce the aircraft accident rate by a factor of five within 10 years and by a factor of 10 within 25 years.
- Reduce emissions of future aircraft by a factor of three within 10 years, and by a factor of five within 25 years.
- Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within 10 years, and by a factor of four within 25 years.
- While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years.
- Reduce the cost of air travel by 25 percent within 10 years and by 50 percent within 25 years.

Pillar Two: Revolutionary Technology Leaps

In addition to the systemic issues associated with the global civil aviation system, there is tremendous opportunity to explore high-risk technology to revitalize existing markets and open new markets. Examination of future trends and various alternatives highlighted the opportunities in high-speed civil transportation, general aviation and experimental aircraft. In addition to new market opportunities, there exist opportunities to revolutionize the way aircraft and space transportation systems are designed and developed. It is also critical to recognize that achieving the goals in all three pillars requires the rapid exploration and validation of concepts and technologies in the flight environment.

The Enterprise and its partners have identified three high-risk enabling technology objectives that can revolutionize air travel and the way in which aerospace vehicles are designed, built and operated:

- Reduce the travel time to the Far East and Europe by 50 percent within 25 years, and do so at today's subsonic ticket prices.
- Invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years and 20,000 aircraft annually within 25 years.

- Provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time in half for aircraft and space transportation vehicles.

Pillar Three: Access to Space

NASA's primary space launch role is to develop and demonstrate pre-competitive next-generation technology that will enable the commercial launch industry to provide truly affordable and reliable access to space. NASA and the U.S. aerospace companies have embarked on an unprecedented partnership aimed at attaining revolutionary improvements in launch system cost, performance, and reliability. In response to National Space Policy and the NASA Strategic Plan, two enabling technology objectives have been identified to dramatically increase the contribution to the National goals in space:

- Develop and demonstrate pre-competitive, next generation technology that will enable U.S. industry to reduce costs by an order of magnitude (to $1000 per pound) within 10 years, and additional order of magnitude (to $100's per pound) within 25 years.
- Achieve a factor-of-ten reduction in the cost of Earth orbital transportation and a factor-of-two-to-three reduction in propulsion system mass and travel time required for planetary missions, within 15 years, and enable bold new missions to the edge of the solar system and beyond by reducing travel times by one to two orders of magnitude, within 25 years.

STRATEGY FOR ACHIEVING GOALS

When the Enterprise identified these three pillars and ten enabling technology objectives, it was recognized that they are highly ambitious and will stretch the boundaries of the U.S. knowledge and capabilities. In order to achieve these National objectives, NASA carries out its aero-space technology mission in close partnership with U.S. industry, academia and other Federal agencies, such as the Department of Defense (DoD) and the Federal Aviation Administration (FAA). During FY 1998, the Enterprise developed detailed roadmaps to define the path that it would need to follow in order to allow this partnership to achieve these objectives. Based upon the current status of our technology development efforts, the scope of what still needs to be accomplished, and given the Agency budget constraints, it is not realistic to expect the accomplishment of all the Enterprise's objectives on the schedule originally envisioned. While all the objectives are being retained, the Enterprise budget has been realigned to concentrate resources on the timely accomplishment of several high-payoff objectives (i.e., aviation safety, capacity, next generation design tools and experimental aircraft, and access to space) that directly impact the general public, have potential for true leapfrog advancements or support NASA's space mission. Progress toward the remaining objectives will be constrained, limiting our effort to fundamental research. This change has necessitated some hard choices in several areas, including the termination of the High-Speed Research (HSR) and Advanced Subsonic Technology (AST) focused programs.

- Although dramatic advances were made against the original program goals, recent market analyses coupled with estimated industry costs for development of $15 to 18 billion have made the high-speed civil transport considerably less attractive to NASA's industry partners. Increasing stringency of noise constraints to ensure an environmentally compatible high-speed civil transport (HSCT) added considerably to the technological risk. Based on the cost of development and the increased risk, market analyses now project the introduction of an HSCT cannot reasonably occur prior to the year 2020. Consequently, industry has reduced their commitment to this area by scaling back their investments, leading to the decision to terminate the focused HSR program at the end of FY 1999.

- Although AST has been a very successful program, budget constraints coupled with the need to refocus our technology efforts toward other objectives resulted in the decision to terminate the program at the end of FY 1999. AST has been the major research and technology activity contributing to progress toward the objectives of the Civil Aviation pillar. The impact on those objectives is:

  - Aircraft emissions: Combustor technologies being developed to address the local regional issue of smog resulting from the emissions of oxides of nitrogen will be reassessed, with the most critical technologies being carried further in the new aircraft engine program described below. However, the effort to assess the impact of aircraft emissions on the atmosphere will be curtailed and the final flight campaign to gather data for that assessment will not be conducted.
  - Noise reduction: Due to the commitments to NASA's partner in noise reduction, the FAA, this work will continue toward its original objective, but no further work is anticipated beyond that objective.
  - Affordable air travel: Those elements focused on the development of pre-competitive, high-risk technologies for low-cost, lighter weight airframe materials and structures and for improved aerodynamic performance, will be terminated. The research directed toward improving the cost and performance of aircraft engines will be examined to determine the most critical technology activities to transfer to the new aircraft engine program described below.

As part of this realignment, the following additions have been made to our program:

- Initiation of a focused effort in Aviation Safety to contribute to the national goal by developing technologies to improve aviation safety through reductions in both aircraft accident and fatality rates. The Aviation Safety program will emphasize not only accident rate reduction, but also a decrease in injuries and fatalities when accidents do occur. The program will also develop and integrate information technologies needed to build a safer aviation system—to support pilots and air traffic controllers—as well as provide information to assess situations and trends that might indicate unsafe conditions before they lead to accidents.
- Augmentation of the Aeronautics Base R&T program to include Revolutionary Concepts (REVCON) and Intelligent Synthesis Environment (ISE) activities. REVCON, a new project in the Flight Research program, will provide the capability to evaluate revolutionary vehicle concepts and advanced high-risk technologies rapidly. ISE, contained within the Information Technology program, will revolutionize the way aircraft and space transportation vehicles are designed by providing new modeling tools and methods to enable rapid in-depth computation of system life-cycles in a networked environment.
- Augmentation of the Advanced Space Transportation program to expand and accelerate Future X/Pathfinder experiments of high-risk, revolutionary space transportation technologies, and cross-cutting synergistic technology developments that have space exploration applications. The additional activities will enhance our ability to investigate the orbit-to-Earth and in-space regime of the flight spectrum to complement existing Earth-to-orbit activities.
- Focusing of remaining propulsion technology into an Ultra-Efficient Engine Technology program to address the critical propulsion issues facing the Nation in the new millennium.

Aeronautical Research and Technology

The aeronautics research and technology program addresses critical aeronautical safety, environmental, airspace productivity, and aircraft performance needs at national and global levels. The necessity to strengthen technology development in selected high-payoff areas is vital to the nation's long-term leadership in aviation, as well as to the value of the national air transportation system.

Pillar One: Global Civil Aviation

Great strides have been made over the last 40 years to make flying the safest of all the major modes of transportation. However, even today's low accident rate is not good enough. In the future, if air traffic triples as predicted, this accident rate will be totally unacceptable. The impact on domestic and international travel will have adverse economic consequences well beyond the American transportation sector. Dramatic steps, through joint FAA, DoD, and NASA research, will assure unquestioned safety for the traveling public.

Aircraft produce a relatively small fraction of the world's air pollution compared to other sources: however, the impacts are often focused, i.e. NO_x emissions around airports, and will continue to grow with the increase in traffic. The U.S. must demonstrate leadership in setting and meeting challenging environmental goals for aircraft. We believe there are technological solutions that will significantly reduce aircraft emissions that contribute to local air quality, global warming and ozone depletion, even as travel volume increases. The NO_x reduction element in the AST program will end with the demonstration of a 50 percent reduction in a full annular combustor versus the Enterprise enabling technology objective of 70 percent reduction in a full-scale engine.

Aircraft noise is the other area where future environmental regulations will challenge us to provide advanced technology concepts and innovations. Previous NASA noise-reduction research is now embodied in new aircraft entering the fleet, and in modifications to existing aircraft. The budgeted program will complete the noise reduction program that was included in the AST program, but this effort will end about 50 percent short of accomplishing the Enterprise goal for perceived noise.

Airlines and businesses lose billions of dollars annually from delays and lost productivity due to weather and congestion in our severely constrained airspace system. In the next two decades 12,000 new commercial airplanes will be required to accommodate the projected growth in travel and to replace older aircraft. Joint NASA and FAA research into unrestricted flight routing, or "free flight," will allow more aircraft to navigate safely in adverse weather conditions throughout more of the Nation's underutilized airspace.

For the aircraft manufacturers, a major challenge is to reverse the trend of increasing costs associated with aircraft ownership and operations that are then passed on to the traveling public. Dramatic time and cost savings in development, production, and certification are needed. The Reduced Seat Cost element of the AST program was formulated to respond to this need. However, budgetary decisions resulted in the cessation of this activity in FY 1999. Significant progress in demonstrating the application of advanced airframe materials to airframe and engine structures and reductions in design cycle time have been made, but short of the Enterprise objective of reducing the cost of air travel.

Pillar Two: Revolutionary Technology Leaps

In the early 1990's, studies indicated that an environmentally compatible and economically competitive High Speed Civil Transport (HSCT) could be possible through aggressive technology development. Since then, NASA concentrated its investments in the required pre-competitive, high-risk technologies. While NASA has continued to be successful and was on track to meet the original program goals, technology advancements in subsonic commercial transports have resulted in a much quieter fleet. The original noise requirements are, therefore, now insufficient for the HSCT to blend into the surrounding aircraft noise levels, and further significant investments in technology development are required to ensure an economically and environmentally viable HSCT. As a result, industry development schedules for an HSCT have significantly lengthened and the likelihood that industry commitment to invest more than $15 billion to launch an HSCT is many years away. For these reasons the HSR program will conclude by the end of FY 1999. The Enterprise's objective in this area will not be accomplished as planned. If the business case improves in the future, activities in high-speed research may be re-evaluated.

As the hub-spoke system congestion increases and air carriers consolidate into larger server providers for larger markets, the general aviation segment of air travel will become increasingly important for travel to and from the Nation's 20,000 suburban, rural and remote communities. This segment of air travel has tremendous potential for growth if several technical issues can be resolved. At its peak in 1978, the U.S. general aviation industry delivered 14,398 aircraft. In 1994, the number of aircraft delivered had fallen to 444, an all-time low. During 1997, the efforts of tort reform in 1994 and the NASA technology investments initiated in general aviation were being felt as deliveries began to increase for the first time in over 15 years. NASA will complete the set of technologies and systems improvements begun under the Advanced General Aviation Technology Experiments project.

Experimental aircraft are invaluable tools for exploring new concepts, and for complementing and strengthening laboratory research. In the very demanding environment of flight, "X-planes" are used to test innovative, high-risk concepts, accelerating their development into design and technology applications. In addition to the tools of flight, next-generation design tools will revolutionize the aviation industry. Design was once solely applying pencil to paper. Research in information technology will leverage the power of computing tools to reduce time and costs associated with aeronautics research through the use of fuzzy logic and artificial intelligence. An Intelligent Synthesis Environment initiative has a long-term vision of an immersive virtual environment in which humans and analytical models can interact visually in a computationally rich mission life-cycle simulation. These tools will integrate multidisciplinary product teams, linking design, operations, and training databases to dramatically cut design cycle times for both aeronautics and space transportation applications.

<u>Advanced Space Transportation Technology</u>

The advanced space transportation technology program addresses the critical technologies required to reduce the costs of access to space, as well as those required for the development of in-space transportation to enable bold new space science and exploration missions.

Pillar Three: Access to Space

High cost and low reliability of today's launch systems hinder the future of the U.S. space program. The cost of access to space is roughly $10,000 per pound of payload delivered to low-Earth orbit. The growth of an otherwise dynamic, creative, and productive

U.S. space enterprise is severely impeded by this daunting price tag. Such high cost, for example, severely limits access to the unique properties of orbital space, thereby significantly reducing the abundant promise of scientific, environmental, and commercial applications that enrich our quality of life on Earth. High cost also means fewer missions of deep-space science and exploration that expand our knowledge of the solar system. In the last 25 years, the U.S. has developed just one major launch vehicle and rocket engine. During the same time frame, our international competitors have developed 27 rocket engines and many more launch vehicles. Our launchers, once preeminent, now supply only 30 percent of the worldwide commercial market. In the world's rapidly expanding launch business, the U.S. continues to lose market share. To realize the full potential for research and commerce in space, America must achieve one imperative, overarching goal: affordable access to space.

Consistent with the National Space Transportation Policy, NASA, as a member of a national team, will develop technology for the next generation space transportation systems, with a target of reducing launch vehicle development and operations costs dramatically after the year 2000. The Reusable Launch Vehicle (RLV) program utilizes innovative, industry-led cooperative agreements to accomplish technology development research and conduct the technology demonstrations necessary to prove the feasibility of the enabling technologies that will lead to significant reductions in launch vehicle development and operations costs. These technologies will be demonstrated by the end of the decade, both on the ground and in flight. The RLV program is structured to respond to the industry's need to reduce or eliminate the technology risk of building a new system. The centerpiece of the program is a series of flight demonstrators (X-33, X-34 and new Future X vehicles) that serve to force technologies from the laboratory into real-world operating environments. Innovative partnerships have been formed that strengthen the alliance between industry and Government, thus eliminating unfocused technology and assuring convergence between commercial capabilities and national needs.

The Advanced Space Transportation Program (ASTP) is developing key technologies to dramatically reduce space transportation costs across the mission spectrum. ASTP will focus on technological advances with the potential of reducing launch costs beyond RLV goals, as well as on developing technology required to support NASA strategic needs to reduce the cost of Earth-orbital transportation and the propulsion system mass and travel time required for planetary missions. The ASTP consists of focused, core and research projects. Focused projects have a strong technology pull based on near-term operational system developments. Core projects push the state of the art in propulsion and airframe systems toward the long-term program goals and objectives. The research projects concentrate on very advanced, breakthrough concepts for revolutionizing space travel.

Industry led Future Space Launch Studies are also underway to provide input to NASA and the Administration for end-of-the-decade decisions on approaches to reducing NASA's launch costs.

Commercial Technology Programs

The third major program area of the Aero-Space Technology Enterprise is the commercial technology program. Since its inception in 1958, NASA has been charged with ensuring that NASA-developed technology is transferred to the U.S. industrial community to improve the competitive position of the U.S. in the world community. The scope of the commercialization effort encompasses all NASA technologies created at NASA centers by civil servants, as well as innovations from NASA contractors. The technology commercialization program consists of: (1) a continuous inventory of newly developed NASA technologies; (2) an up-to-date searchable database of this inventory; (3) assessments of the commercial value of each technology; (4) dissemination of knowledge of these NASA technology opportunities to the private sector; and (5) support of an efficient system for licensing NASA technologies to private companies. In addition, NASA commercialization efforts also include the operation of the Small Business Innovation Research program, which is designed to enhance NASA's use of small business technology innovators and lead to increased commercialization of NASA technology with small firms.

SCHEDULE & OUTPUTS

The Enterprise has developed, utilizes, and is continually applying and refining a family of performance measures to assess both program progress and relevance to external customer requirements. These measures include:

Program Performance. Measures of program performance that contribute to the achievement of the Enterprise goals:

- Implement the Aero-Space Technology Enterprise programs in an effective and efficient manner and complete customer-negotiated product and service deliverables (identified as milestones in formal program plans) within three months of plan.
- Increase technology transfer activities with the aerospace community by transferring at least twelve new technologies and processes to industry during the fiscal year.

Customer Satisfaction. Measures of customer satisfaction with respect to Enterprise products and services:

- Ensure the availability of quality facilities for the Enterprise's customers by measuring levels of satisfaction with capabilities and services through conduct of exit interviews at selected facilities.
- Satisfy the Enterprise's customers with quality products and services by measuring overall customer satisfaction through formal, triennial customer surveys.

Other Organizational Goals and Processes. Measures of performance relative to other policies and goals:

- Provide important contributions to education and public understanding of air and space transportation by developing an education outreach plan for all new programs that includes and results in an educational product.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY **AERONAUTICAL RESEARCH & TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998	FY 1999	FY 2000	Page Number
	(Thousands of Dollars)			
Research and technology base	428,300	424,100	425,800	SAT 4.1-2
Aeronautical focused programs	491,800	344,800	194,200	SAT 4.1-22
Total	920,100	768,900	620,000	
Distribution of Program Amount by Installation				
Johnson Space Center	669	1,085	0	
Marshall Space Flight Center	2,302	2,428	2,133	
Ames Research Center	229,699	198,040	196,711	
Dryden Flight Research Center	93,425	77,809	91,405	
Langley Research Center	325,008	265,633	163,329	
Glenn Research Center	249,992	206,832	158,235	
Goddard Space Flight Center	5,566	7,244	0	
Jet Propulsion Laboratory	1,387	1,769	0	
Headquarters	12,052	8,060	8,187	
Total	920,100	768,900	620,000	

BASIS OF FY 2000 FUNDING REQUIREMENT

AERONAUTICS RESEARCH AND TECHNOLOGY BASE

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Information Technology	72,800	66,500	90,100
Airframe Systems	140,400	138,500	137,900
Propulsion Systems	72,000	75,400	66,200
Flight Research	82,100	70.600	87,700
Aviation Operations Systems	28,400	43,400	17,000
Rotorcraft	32,600	27,200	26,900
Construction of Facilities		2,500	(10,700)*
Total	428,300	421,600	425,800

*Program Direct Construction of Facilities funds in FY 2000 included within other R&T Base elements.

PROGRAM GOALS

The goal for NASA's Aeronautics Research and Technology (R&T) Base is to serve as the vital foundation of expertise and facilities that consistently meets a wide range of aeronautical technology challenges for the nation. The R&T Base is intended to provide a high-technology, diverse-discipline environment that enables the development of new, even revolutionary, aerospace concepts and methodologies for applications in industry. Each program of the R&T Base has an objective to develop multidisciplinary methods and technology that contributes to one or more of the Aero-Space Technology Enterprise goals. In particular, the initial $500M commitment over five years of the Enterprise to achieve the goals of the Administration's Aviation Safety Initiative was initially supported from reinvestments made within the R&T Base. Work within the R&T Base lays the foundation for future focused programs to address the long term goals of the enterprise's Three Pillars. This work constitutes a national resource of expertise and facilities that responds quickly to critical issues in safety, security, and the environment. These same technological resources contribute to the overall U. S. defense and non-defense product design and development capabilities.

STRATEGY FOR ACHIEVING GOALS

The technology environment for success in aerospace is characterized by continuous advances across a wide range of disciplines, as well as developments of revolutionary technology. With the downsizing of research facilities and basic research capabilities in industry and government agencies, the R&T Base is critical in the continual struggle for technological preeminence in the world-wide aerospace scene. Through basic and applied research in partnership with industry, academia, and other government agencies, NASA develops critical high-risk technologies and advanced concepts for U. S. aircraft and engine industries. These advanced concepts and technologies allow a safe, highly productive global air transportation system that includes a new generation of environmentally compatible, economical U. S. aircraft that are competitive in the marketplace.

The R&T Base is an essential element of the Enterprise, for it is here that new technologies that lead to future advanced aerospace products are conceived. Providing a strong foundation for the fundamental understanding of a broad range of physical phenomena, development of computational methods to analyze and predict physical phenomena, and experimental validation of key analytical capabilities. The R&T Base also develops revolutionary concepts, highly advanced, accurate computational tools and breakthrough technologies that can reduce the development time and risk of advanced aerospace systems and high performance aircraft. A significant portion of the research and concept development in the R&T Base is performed through partnerships and cooperative agreements with the aerospace industry and other government agencies to facilitate rapid technology transfer. Also, the R&T Base supports the vast majority of the Enterprise's peer-reviewed fundamental research with academia and industry. The program also provides the capability for NASA to respond quickly and effectively to critical problems identified by other agencies, industry or the public. Examples of these challenges are found in: aircraft accident investigations, lightning effects on avionics, flight safety and security, wind shear, crew fatigue, structural fatigue, and aircraft stall/spin.

One of the key factors in aeronautical research is an extensive use of research facilities that are located at the four aeronautical research centers: 1) Ames Research Center, 2) Dryden Flight Research Center, 3) Langley Research Center, and 4) Glenn Research Center. Many facilities, such as the National Transonic Facility, the National Full-Scale Aerodynamics Complex, the Icing Research Tunnel and the fleet of research aircraft are unique in the U. S. and even the world. Other factors underpinning continued governmental support of aeronautical research include: the public-good character of much of the research (safety, environment, certification, national security); large disincentives for private sector investment in long term, high risk aeronautical R&T, since an individual company can rarely capture the full benefit; the length of time for the aircraft research-and-development cycle and the total investment recoupment period; the extensive breadth and depth of technologies required to produce a superior aircraft; and the unique cadre of experienced NASA technical personnel.

The Aeronautics R&T is a framework of six systems oriented, customer driven programs, that serve the needs of the full range of aeronautical vehicle classes. The six R&T Base programs are:

1. Information Technology: The primary focus of this program is on the development of computational tools and integrated systems for the design and manufacture of flight vehicles and systems.

2. Airframe Systems: The Airframe systems technologies have application to all flight vehicles that operate in the atmosphere with emphasis in areas such as: conceptual design; aerodynamic and structural design and development; flight crew station design; and airborne systems design and testing.

3. Propulsion Systems: The purpose of this program is to design and develop efficient, safe, affordable and environmentally compatible propulsion system technologies for subsonic and high speed transports, general aviation and high performance aircraft.

4. Flight Research: The technology development under this program is aimed at remotely piloted aircraft, high performance aircraft, hypersonics, and tools and test techniques

5. Aviation Operation Systems (AOS): The AOS program is structured to address critical technologies in communications, navigation and surveillance systems, air traffic management, relevant cockpit systems, operational human factors, and weather and hazardous environment characterization and avoidance systems.

6. Rotorcraft: The rotorcraft program meets the challenge of technology leadership by developing: technology for improved flight safety; technology for reduced noise for passengers and the community; and design tools for reduced design-cycle time and reduced manufacturing costs.

Additionally, the R&T Base includes facilities that directly support Aeronautical research.

Accomplishments over the past year continue to provide a foundation for longer term technology development to address national needs as outlined in the Enterprise's Three Pillars for Success, and to provide research facilities operations and expert consultation for industry during their product development design and build processes. Conceptual studies took into consideration various state-of-the-art technologies to reduce aircraft design and manufacturing costs and addressed breakthrough technology requirements for future commercial and general aviation transports, rotorcraft, hypersonic vehicles, as well as high performance and high altitude remotely piloted aircraft. The R&T Base continues to sponsor and conduct research using cooperative programs, not only to leverage resources for technology development, but also to ensure timely technology transfers to U. S. customers.

SCHEDULE AND OUTPUTS

Information Technology

Acquire and install High Speed Processor 4. Plan: September 1998 Actual: September 1998	Delivered to Numerical Aerodynamics Simulation (NAS) community a demonstrated capability of a symmetric multi-processor to deliver scaleable performance at less than 25% of the cost of High Speed Processor (HSP) 3.

Demonstrate knowledge system prototype in test facility. Plan: September 1998 Actual: September 1998	Demonstrated reduction in design cycle time by the application of intelligent information analysis and unified instrumentation.
Adaptive coefficient based controller flight demonstrated in shadow mode on the F-15 ACTIVE aircraft. Plan: December 1998 Revised: March 1999	Achieve neural net reconfiguration in flight. Milestone slip due to projected late availability of flight test vehicle.
Demonstrate prototype heterogeneous distributed computing environment Plan: September 2000	Demonstrate tools and software to link distributed computing test-beds at multiple NASA Centers into a single "virtual" supercomputing environment.
Demonstrate real-time aerospace design exploration Plan: September 2000	Demonstrate real-time access to computational simulations, experimental data sources and archived data for aerospace design exploration.

Airframe Systems

Complete flow physics data for 2-D high-lift methods Plan: September 1998 Actual: September 1998	Benchmarked data-set acquired for validation of CFD codes
Complete Mach 7 Research Vehicle tests in LaRC's 8-foot High-Temperature Tunnel. Plan: March 1998 Actual: June 1998	Completed system check-out in Mach-7, flight-type environment and obtained ground based data for direct comparison with flight.

Verify Electromagnetic Emissions (EME) immunity procedures to emulate specific aircraft EME environment. Plan: September 1998 Actual: September 1998	Completed High Intensity Radiated Fields (HIRF) Laboratory tests to verify EME immunity procedures. Test procedures developed and presented to RTCA, Inc. and FAA Electromagnetic Committees.
Develop technologies for smart aircraft systems to provide cost-effective improvements in boundary layer control. Plan: September 1999	Implementation of active control for 20 percent increase in airfoil maximum lift coefficient.
Mach 7 Research Vehicle Flight. Plan: January 2000	Successfully accomplish research objectives of the dual mode scramjet powered flight tests.
Flight Validation of Falling Leaf criterion Plan: March 2000	Flight Validated design tool for predicting and avoiding loss of control (Falling Leaf) in high performance aircraft
Full-scale shape memory alloy (SMA) nozzle control demonstrated Plan: September 2000	Demonstrated feasibility of full scale SMA nozzle at simulated operating loads
10 dB community noise impact reduction. Plan: September 2000	Subscale validation of technology to reduce community noise impact by 10 dB relative to 1992 technology. High fidelity engine simulator tests in wind tunnels will be used to demonstrate 6 dB engine noise reduction and 50 percent nacelle liner improvement. Similarly, flap, slat and gear airframe noise reductions resulting in a 4 dB total airplane airframe noise reduction will be demonstrated in model-scale wind tunnel tests.
Validate affordable General Aviation avionics system architecture. Plan: September 2000	Validate COTS-based technology for affordable, highly integrated, open architecture, modular avionics system for Highway in the Sky graphical operating capability.

Propulsion Systems

Complete engine fabrication for advanced general aviation turbine and intermittent combustion engines. Plan: September 1998 IC Engine Actual: September 1998 Turbine Engine Actual: December 1998	Complete fabrication in time to meet FY 2000 flight test schedules. Intermittent Combustion Engine: First engine assembled and tested. Turbine Engine: First build of all major components rig tested. Completing fabrication of the first turbine engine slipped due to a turbine component manufacturing error. A second turbine component was manufactured successfully and the engine was successfully assembled in December. This slip will have no impact on future milestones.
Provide materials and processing for turbine inlet temperatures above 2,400°F. Plan: June 1999	CMC specimen with cooling holes successfully survives burner test.
Complete engine pre flight ground tests for GAP engines. Plan: September 1999	Complete altitude test of the turbine engine and the sea level test of intermittent combustion engine at NASA test facilities.
Complete flight demonstration of GAP engines. Plan: September 2000	Flight demonstrate the intermittent combustion engine and the turbine engine at Oshkosh Air Show.
Demonstrate 900°F SiC sensor on an engine. Plan: September 2000	Commercial grade, high temperature sensor demonstrated at 900°F.
Demonstrate 'smart' turbomachinery concepts to minimize pollutants throughout mission cycle. Plan: September 2000	Active combustion control strategy rig demonstrated; 20dB suppression of instability driven acoustic energy.

Flight Research

Complete X-36 flight evaluation.	Complete flight objectives and analysis of vehicle performance.
Plan: June 1997 Actual: December 1997	Delay was due to the systems and software development for the flight vehicle. Highly successful flight evaluation achieved all program objectives. Measured performance exceeded predictions. Provides credible database for tailless fighters of the future.
Flight-demonstrate an inlet-distortion-tolerant control system.	Evaluate in flight, on the Advanced Control Technology Integrated Vehicle (ACTIVE) aircraft, a high-stability, integrated control system using sensed inlet distortion to enhance stability.
Plan: September 1998 Actual: June 1998	Data analysis of data demonstrated increased engine stability through the high stability integrated control system using sensed inlet distortion.
Complete piston-powered turbocharged RPA flight for 8 hours at 60,000 feet.	As part of ERAST demonstrate record-breaking high-altitude duration capability to validate the capability for science missions of greater than 4 hours duration in remote deployments to areas such as the polar regions above 55,000 feet.
Plan: September 1998 Revised: March 1999	Delayed due to lubrication and cooling system problems
Complete significant advance in flight visualization measurement techniques.	Flight evaluation of flight measurement and test techniques including in-flight Schlieron imaging system and in-flight infrared transition detection system.
Plan: September 1999	
Flight demonstrate dropping-of-windsonde compatibility with RPA at altitudes above 55,000 feet.	Demonstrate the utility of carrying and delivering miniaturized windsondes (wind measuring sensors) to obtain meteorological data with the Altus Remotely Piloted Airplane up to 55,000 foot altitude.
Plan: September 1999 Actual: Deleted	Deleted due to ERAST re-planning to better develop technology for operational vehicles to meet the science community needs.
Complete low altitude flights of Centurion	Demonstrate systems functionality of remotely piloted aircraft with wingspan greater than 200 feet, suitable for flight to 100,000 feet in altitude once outfitted with high performance solar cells.
Plan: January 1999	
Demonstrate 2 aircraft formation flight utilizing autonomous	Demonstrate functionality of autonomous station keeping on two F-18's in support of establishing practical operability of precision formation flight for drag reduction and

station-keeping controls Plan: January 2000	consequently reduce fuel burn.
Complete low-altitude flight of Helios Plan: March 2000	Demonstrate a solar-powered remotely piloted aircraft with wingspan greater than 250 feet suitable for flight to 100,000 feet in altitude or a duration of 100 hours once outfitted with high performance solar cells
Complete assessment of science mission demonstration Plan: September 2000	Complete assessment of remotely piloted aircraft science mission capability based on experience from two or more platform configurations applied to different mission requirements and science sensors independently selected by user community.

Aviation Operations Systems

Complete icing-tunnel database of ice shapes for modern airfoils. Plan: June 1998 Actual: August 1998	Completed tests in Glenn Research Center Icing Research Tunnel. Identified key two-dimensional ice shapes for modern airfoils. Leading-edge models were provided for aerodynamic wind-tunnel testing at Langley Research Center.
Complete flight tests and instrumentation comparison for the NASA/AES Joint Super-cooled Large Droplet (SLD) icing program. Plan: June 1999	Develop SLD icing research data acquisition and processing methods through joint SLD flight operations and collaborative instrumentation development with the Canadian agency.
Develop the model of human memory constraints in reactive planning and procedure execution. Plan: September 1999	Demonstrate, using full mission simulation, safety benefits of automation design using models of human memory.
Define framework for cost-benefit model consistent with NAS and human performance. Plan: September 2000	Define overall framework for cost-benefit model integrating (National Airspace System (NAS) and human performance models.

Conduct representative safety analysis for air-ground automation and operational procedures. Plan: July 2000	Conduct a representative safety analysis for air-ground automation and operational procedures to validate a theory-based methodology for predicting operational error-vulnerability.

Rotorcraft

Validate advanced computational methods for the prediction of rotor/airframe interaction and unsteady aerodynamics with data acquired from advanced laser velocimetry techniques. Plan: January 1998 Corrected: January 1999 Revised: March 2002	Assess the accuracy of unsteady computational aerodynamic predictions of rotor/fuselage aerodynamic interference, based on validation using advanced, non-intrusive, three-dimensional flow measurements. Milestone date was incorrectly reported in FY 1999 narrative. During that initial test entry, significant difficulties were encountered with acquiring the unsteady Doppler Global Velocimetry (DGV) (first time that unsteady DGV had ever been attempted in a wind tunnel). As a result of extreme demand on the facility (14- by 22-Foot Subsonic Tunnel) and two scheduled shutdowns of that facility for upgrades, it is unlikely that the next attempt to acquire unsteady DGV data on a rotor in forward flight will occur before 3rd quarter FY01. Therefore, the completion of the milestone was rescheduled for 2nd quarter FY02.
Demonstrate Master Cure Simulation System (MCSS) for manufacturing thick-composite rotorcraft structures. Plan: September 1998 Revised: June 1999	Under National Rotorcraft Technology Center (NRTC), validate and demonstrate that master cure process molding and controller accurately predict/control thick-composite-material behavior and its rate of cure. Additional testing required to refine processes; fabrication of demonstration component rescheduled to reduce costs.
Demonstrate high-quality, low-cost composite manufacturing of critical rotorcraft components using resin transfer molding process. Plan: September 1999	Improve cost and reliability of components using resin transfer molding process for actual hardware.

Validate prediction of main rotor noise as measured during flight tests, by comparison of measured helicopter footprints with predictions. Plan: September 1999	Provide flight validated computational codes for the prediction of helicopter noise footprints.
Flight demonstrate active control technology for rotorcraft interior noise reduction; provide interior noise prediction methods for a range of rotorcraft types. Plan: December 1999	Validated technology for interior low noise design.
Flight validate advanced control laws/modes for reduced pilot workload and increased safety in low visibility using integrated design tool (CONDUIT). Plan: March 2000	Demonstrate industry confidence in CONDUIT as a low cost control law development and optimization tool.

ACCOMPLISHMENTS AND PLANS

Information Technology

In FY 1998, the Information Technology program developed a knowledge-based design system prototype and demonstrated the technology in a wind tunnel test environment. This system acquired data from experiments and numerical simulations, rapidly analyzed the data and provided advisories to design engineers regarding the results and opportunities for design improvements. This system allowed engineers to redesign a flap element of a subsonic transport high-lift system and to retest the newly designed component during the same wind tunnel test entry. The ability to save a cycle of wind tunnel testing required for preliminary design and the potential to significantly reduce design cycle time has been demonstrated. Also completed in FY98 is an intelligent flight control system. In collaboration with The Boeing Company, the newly-developed system is a major step forward in demonstrating the potential to regain safe, controllable flight characteristics after a major change such as a damaged wing, greatly increasing the chances for survival and safe return under such circumstances. The intelligent flight control system will be flight tested on board an F-15 flight research aircraft at the beginning of FY 1999. A communication system for the aviation community is being developed that will enable aviation safety information to be accessed, analyzed, and disseminated rapidly throughout the National Airspace System, helping to reveal current risk factors, identify emerging trends, and address the most important issues in aviation safety.

Key connections with operational ground facilities and airlines for real-time aircraft performance data have been completed. A new high-speed processor, HSP-4, has been obtained and integrated into the aeronautics supercomputing system. This machine has demonstrated sustained processing speeds of 20 GFLOPS (billion floating-point operations per second) for realistic aerospace design and analysis problems with highly favorable price-to-performance metrics. Tools and techniques to generate safe software automatically for complex, flight-critical systems at greatly reduced time and cost continue to be developed, as well as the means to protect and verify the integrity of data communications within the aviation system.

In FY 1999, the Information Technology program will further develop integrated design techniques, including wind tunnel flow quality and testing productivity enhancements, more accurate model positioning and balance calibration systems, on-line real-time test data and more versatile user interfaces. Of particular focus within the integrated design effort will be to transition the technology from aircraft to space transportation systems. Specifically, the integrated design tools will be adapted and applied to thermal protection system design of reusable launch vehicles. Together with advanced instruments and data acquisition systems, this effort will continue the development of capabilities for real-time design exploration of aerospace vehicles. An intelligent, neural-network flight control system will be flown on an F-15 research aircraft, and work will be initiated to integrate this capability with propulsion control, health monitoring and diagnosis capabilities. Intelligent tools for an aviation safety data sharing network will be developed and a prototype data sharing network will be established. An effort to demonstrate real-time data sharing with a flight vehicle is planned. Next-generation computing systems will be developed that take advantage of geographically distributed resources, requiring new capabilities in network quality of service, data storage, retrieval and analysis, and system operations including scheduling, planning, and accounting. Software technology developments will contribute to enhancing the reliability of complex, flight-critical systems (such as flight control systems), and reducing the cost of producing, verifying, and validating these systems. Tools for ensuring and verifying the integrity of wireless data communications will be developed and demonstrated to enhance the safety of the future National Airspace System.

In FY 2000, the Information Technology program will complete a demonstration of real-time aerospace design exploration. The developed environment will include remote connectivity, access to experimental data in real-time, capability to perform simulations in near-real-time, and access to databases with analysis tools to support design. All of these capabilities will be coupled with newly-developed instrumentation and data systems to provide previously unavailable experimental data. In addition to reductions in access time to high-fidelity simulations data, specific goals of the system include a reduction in access time to experimental data by a factor of five, and a reduction in access time to archived database sources by a factor of two. Improvements in software technology will result in the development of verifiably-correct program synthesis technology. Tools will be demonstrated to reduce time in software coding and testing. Specifically targeted applications will demonstrate these tools on real-world, complex software development activities meeting NASA mission requirements. Finally, the first prototype of a geographically-distributed heterogeneous high-end computing system will be developed and demonstrated for NASA supercomputing requirements. The developed software tools will link multiple NASA supercomputing assets seamlessly and transparently to the end-users. The overall computing capability enabled by this technology will allow for geographically dispersed engineering collaboration and greater peak computing power. The Information Technology program also includes Intelligent Synthesis Environment (ISE), which will revolutionize the way aircraft and space transportation vehicles are designed by providing new modeling tools and methods to enable rapid in-depth computation of system life-cycles in a networked environment. The ISE efforts will be focused in two specific areas: (1) collaborative engineering environments (CEE) and (2) rapid synthesis and simulation tools (RSST). In CEE, geographically distributed collaborative teams will apply user-ready, state-of-the-art tools to life-cycle assessments of Enterprise-focused mission applications and will develop advanced engineering processes that will be able to exploit advanced design and analysis tools. In RSST, activities will be initiated to provide new modeling tools and methods for engineering and science systems, to enable rapid in-depth computation of system life-cycles in a networked environment.

Airframe Systems

In FY 1998, the **Airframe Systems** program developed technology in the areas of safety, environmental compatibility, affordable air travel, next-generation design tools and experimental aircraft. A top-down conceptual error-proof flight deck design with traceability to human-centered design guidelines and philosophy was completed. Tests in wind tunnels have been conducted to model the aerodynamic forces mathematically to produce realistic simulations for future simulators which are a valuable tool for pilot training. A reverse geometry x-ray system was developed for detection and quantification of corrosion in aircraft structure. To enhance environmental compatibility of aircraft, studies were completed on active control of jet noise emissions for reduced community noise. Surface shape change and doublet device modeling concepts were formulated leading to a control system that is effective for aircraft utilizing novel aerodynamic flow control actuators. A method was also developed to find optimized piezoelectric actuator locations for active structural acoustic control. Key technology barriers for future subsonic transports were addressed including advanced vehicle configurations such as the Blended Wing Body (BWB). Successful tests of the BWB configuration were completed. Cost and performance benefit over conventional configuration show this aircraft concept has improved lift-to-drag and reduced fuel burn and takeoff weight. Performance assessment of machined and extruded integrally stiffened curve fuselage panels was completed for possible reduction of aircraft weight and cost with no loss in durability or damage tolerance. Crack turning was incorporated into a finite element model. A series of experiments were completed to develop turbulence models to accurately predict detailed characteristics of turbulence vortex breakdown flows. To provide a validation database and to better understand the fundamental flow physics associated with high-lift systems, detailed measurements for transition and Reynolds stress profiles were obtained. Transition modeling, which was not incorporated into computational fluid dynamics (CFD) codes, was integrated with turbulence modeling for high-lift flows. Order of magnitude decreases in design cycle time are occurring through aerodynamic and finite element method code integration. Airframe Systems continued assistance in solving technical problem with existing aircraft. A breadboard buffet alleviation system has been developed and experimentally tested which indicates an order of magnitude improvement to the vertical tail fatigue life. A flight recovery technique was developed in simulation for the out-of-control "Falling Leaf" phenomenon. NASA expertise is being utilized in the development of the Joint Strike Fighter via experimental test results. The first Hyper-X research vehicle (HXRV) and launch vehicle have passed critical design reviews. Most of the HXRV structure has been fabricated and assembled, and the launch vehicle rocket motor delivered. Preflight testing of aerodynamic, propulsion and stage separation continued throughout the year. Preparations were nearly complete for a full flowpath test of the flight engine mated to a full-scale wind tunnel model of the HXRV. In FY 1999, the Airframe Systems program will develop technology in safety including complete simulations of crew workload displays. This will be used to help reduce accidents caused by human errors in the flight deck. Nondestructive evaluation techniques will be developed for improvement in crack detection in thick structures by a factor of two. To enhance environmental compatibility, breakthrough technologies in active structural control that allow for significant reduction in aircraft bending loads will be developed. The Airframe Systems Program will address key technology barriers for future subsonic transports. This includes developing aircraft controller strategies for enhancing performance and reconfiguration capabilities. Wind tunnel tests will be conducted to understand the flow physics and the characterization of abrupt wing stall, an uncommanded, abrupt roll perturbation during elevated load factor turns. Validated design criteria to address the out-of-control "falling-leaf" phenomenon associated with fighter aircraft will be provided. The Hyper-X Program will continue to support the goals of the Access-to-Space Pillar. Test will begin on the full-scale model of the HXRV. Comparison of CFD performance prediction and correlation with wind tunnel data will also begin.

In FY 2000, the Airframe Systems program will continue to develop technology in the areas of safety, environmental compatibility, affordable air travel, next-generation design tools and experimental aircraft. Comprehensive systems level assessment approach for evaluating the effects of electromagnetic disturbances on critical control computers, and electromagnetic environment (EME) immune flight critical systems will be designed. To enhance environmental compatibility, technologies will be developed to reduce emissions and drag using smart devices with active components. High-payoff, innovative control concepts will be developed and demonstrated. The BWB drop model test will be completed. Conceptual designs of two advanced configuration aircraft will be completed. High-fidelity multi-disciplinary methods for nonlinear problems will be demonstrated. A method to assess the priorities of the Research and Technology projects and to quantify cost of basic research will be delivered. The first flight test of the HXRV will be completed. Also a large-scale airframe noise experiment will be conducted to validate noise reduction concepts. Overall program objectives of 6 dB engine noise reduction, 50 percent liner improvement, 4 dB airframe noise reduction, and 6 dB interior noise reduction, all relative to 1992 production technology, will be confirmed through validated system analysis tools. An affordable general aviation integrated avionics system will be validated and work will continue on the development of a "highway-in-the-sky" operating capability for demonstration in 2001. Manufacturing methods for the new generation of advanced general aviation aircraft, additional training modules in the flight training curricula, the multifunction display guidelines, a low-cost communications, navigation and surveillance system, and a highly integrated open architecture avionics will be completed.

Propulsion Systems

The Propulsion Systems program develops technology that supports all Three Pillars for Success. In FY 1998, the General Aviation Propulsion project focused on fabrication and component tests for the intermittent-combustion and turbine engines scheduled for flight demonstrations in FY 2000. Among other activities, there was a validation of integrated design and process technologies for forged components, permitting a potential 50% reduction in development time and cost. Validated turbine cooling passage computation methods for design of turbines with reduced cooling flow requirements were also developed. The emissions goal is being addressed by the initiation of active combustion instability control effort, and by initial demonstration of better than 70% reduction in NO_x with wall-injection Lean Direct Injection concept. Progress was made toward the goal of increasing turbine inlet temperatures above 2400°F by developing a laminated object manufacturing process, and a method for producing cooling channels. In preparation for a demonstration of 900°F silicon carbide sensor on an engine in FY 2000, there was a demonstration of silicon carbide integrated circuit operation at 1100°F. Some critical component concepts were defined for hybrid propulsion systems capable of hypersonic flight. The High Performance Aircraft sub-element continues active technology validation activities in coordination with DoD. A new project was initiated to improve engine safety by reducing engine component failure to an absolute minimum and containing all possible fragments if an unexpected failure does occur.

During FY 1999, the General Aviation Propulsion project will conduct pre-flight ground tests of the intermittent-combustion and turbine engines in preparation for flight demonstrations in FY 2000. Among other activities, advanced material and process systems capable of turbine inlet material temperatures above 2400°F will be demonstrated. Work will continue on the development of 900°F silicon carbide sensors models, and concepts will be delivered that enable reductions in cost and risk barriers for selected advanced turbine engine components. The High Performance Aircraft project will continue active technology validation activities in coordination with DoD. There will be an effort toward developing critical air-breathing launch vehicle component technology scheduled for validation in FY2000. The effort to improve engine safety also continues with emphasis on development of more crack resistant alloys for blades and disks, and improved containment system.

During FY 2000, the General Aviation Propulsion project will conduct flight demonstrations of the intermittent-combustion engine and the turbine engine at the Oshkosh Air-show. These flights will demonstrate a new generation of general aviation propulsion systems that are revolutionary in affordability, ease of use, and performance. These new engines, with their smooth, quiet operation, promise to be the key to creating new demand for aircraft and revitalizing the U.S. general aviation industry. Among other activities, there will also be a demonstration of a 900°F silicon carbide sensor on an engine. This demonstration is a daring leap from laboratory development of SiC pressure sensor and electronics into a real application in the harsh engine environment, that could, if successful, lead to sensor development for many commercial and military applications. Active combustion instability control will form the cornerstone of demonstrating "smart" turbomachinery concepts to minimize pollutants throughout a typical mission. The technology that will be rig demonstrated, a 20dB suppression of instability driven acoustic energy, is a critical enabling technology for stable operations under lean combustion conditions that can potentially lead to as much as 80% No_x reduction in the future. Validation ground testing of air-breathing launch vehicle critical component technology is planned, along with the development of an air-breathing launch vehicle reference vehicle concept. The effort to improve engine safety will continue to seek alloys for blades and disks which are more crack resistant for delivery in FY 2001, while a subscale containment system will be evaluated this year. The High Performance Aircraft project will continue active technology validation activities in coordination with DoD.

Flight Research

In FY 1998 the Flight Research program, under the environment goal, accomplished a significant achievement with the highlight coming with a world-record breaking flight of the solar-powered Pathfinder Plus Remotely Powered Airplane (RPA) to an altitude of 80,200 feet. This RPA technology will increase the Nation's capability to make scientific sampling high in the atmosphere. In pursuit of improved aviation safety, a new effort began to help transition technology into use by the air transportation industry. This technology will be drawn from the other program elements, and make use of testbed aircraft to raise the technology readiness level. In pursuit of efficiency and affordability, the Systems Research Aircraft completed the Electrically Powered Actuator Development Flight experiments activity, which includes several types of electrical actuators. In pursuit of improved US aircraft and engine performance, within the Integrated Controls area, the Advanced Control Technologies for Integrated Vehicles completed the characterization of the axisymetric thrust vectoring. The ground testing of the closed loop mult-iaxis vectoring nozzles, coupled through a fully integrated interloop flight control system was also completed. In pursuit of high-speed travel, US pilot handling quality evaluations of the Tu-144 were completed. Under an advanced concept activity, several efforts are underway. In an international cooperative program, a scramjet built by the Russian Central Institute of Aviation Motors completed its flight test, providing pristine data on the transition from subsonic (ramjet) to supersonic (scramjet) modes..

During FY 1999, the Flight Research program continues to develop concepts through ERAST, including the demonstration of multistage turbocharged RPA to 60,000 feet for an 8 hour duration. Also, flights will continue with the Centurion solar-powered airplane which will be designed to eventually reach 100,000 feet altitude. This RPA technology will increase the Nation's capability to make scientific sampling high in the atmosphere. In pursuit of improved aviation safety, the effort to help transition technology into use by the air transportation industry will completed. This technology will be drawn from the other program elements, and make use of testbed aircraft to raise the technology readiness level. In pursuit of efficiency and affordability, an F-18 testbed aircraft will be modified to investigate Active Aeroelastic Wing (AAW) technology in preparation for the flight tests, which will begin in FY 2000. In support of the efficiency and affordability goal, the flight assessment of the advanced actuators flight experiment using the F-18 Systems Research Aircraft will be completed. Under advanced concepts, the PHYSX test program, a Pegasus launch vehicle with a wing glove fixture measured the cross-flow boundary layer at hypersonic (Mach 8) speed, providing critical design data for vehicles that will provide access to space. The flight experiment was flown in November 1998 and was completely successful. In the continuing effort to improve flight research tools and test techniques, a significant advance in flight visualization measurement techniques is planned to be fully demonstrated in flight.

The Flight Research program in FY 2000 will be developing further capability for increased altitude using ERAST remotely piloted airplanes (RPA). The Centurion solar-powered RPA designed for flight to 100,000 feet will be modified to a longer wingspan configuration, named Helios. This configuration will be more suitable for extreme endurance as well as short flights to the 100,000 ft. altitude. It will be demonstrated ready for later upgrade to high-efficiency solar cells and the maximum altitude missions. In pursuit of efficiency and affordability, an F-18 testbed aircraft will have been modified to investigate Active Aeroelastic Wing (AAW) technology and completed its first flight. A new effort will be initiated under the X-plane goal, but with applicability to a number of the other goals. Under the name revolutionary concepts, or REVCON, the design and development of a blended wing body sub-scale X-plane will be initiated. This X-plane will be dropped at high altitude from under the wing of the B-52, with the objective of obtaining flight test data on the transonic characteristics of the revolutionary concept. With the first flight in 2001, the new shape is expected to offer major contributions to the goals of increased capacity, reduced emissions, increased throughput and increase mobility. Under the reduced emissions goal, the advanced flight concepts will explore use of precision formation flight in order to reduce overall drag, and consequently reduce fuel burn. The concept will be demonstrated with two F-18 aircraft and automated formation flight system. In the continuing effort to improve flight research tools and test techniques, a significant advance in in-flight sensors for propulsion, aerodynamics and structure-related measurements are planned to be fully demonstrated in flight.

Aviation Operations Systems

In 1998, an icing condition called "Super-cooled Large Droplets" (SLD) was characterized by flight tests. This flight data provides the first measurement of actual sizes and numbers of droplets in natural SLD icing conditions. In partnership with FAA and industry, NASA demonstrated the capability to use airborne lasers for all-weather turbulence detection including a flight evaluation in Juneau, Alaska. The capabilities of the Advanced Performance Measurement system for routinely converting flight-recorded data into information has been declared operational at one airline and successfully demonstrated at a second airline involving a larger fleet of more modern aircraft. A new model-based evaluation methodology that enables prediction of vulnerability of human-automation systems to human error was developed.

During FY 1999, the Aviation Operations System program was re-planned to respond to the President's safety goal of reducing aviation accidents by 5 fold in 10 years. A model of human memory constraints in procedure execution and reactive planning will be developed. This model will be used to guide design of automation to aid air traffic service providers, airline operations center personnel and flight crews to assure automation support consistent with human performance characteristics. Working with industry, the program will continue to improve the effectiveness of ice protection systems and reduced development and certification cycle & costs for industry. International collaboration, needed for dramatic improvements in aviation safety, will be strengthened by a joint Super-cooled Large Droplet (SLD) icing research conducted with AES (Atmospheric Environment Sciences) of Canada. To enhance safety, an increased emphasis is being put on the development of procedures and innovations to clarify the roles and responsibilities of aircraft maintenance teams. In addition, to reduce weather related accidents, systems for communicating and displaying real time weather information to airborne and ground base users will be pursued in collaboration with industry and DoD, FAA and NOAA/NWS. Initial flight tests will be conducted.

During 2000, the Aviation Operations System program will continue its focus on developing more basic concepts, procedures and systems to remove the key barriers to significant improvements to the safety of the nation's aviation system. A new project to develop a cost/benefit model to analyze new technologies including the effects of human performance will be developed. It will uniquely focus on integrating systems and human performance modeling, and will develop a modeling framework. Fundamental modeling of human performance will incorporate visual motion and eye movement parameters in computational models of human vision. Automation system functional model decomposition methods are being matched to human performance constraints and biases. The result is a theory-based methodology for predicting operational error-vulnerability. This method will be empirically validated through a representative safety analysis for air-ground automation and operational procedures. Ultimately this will result in a computational model matching human/system performance and error trends.

Rotorcraft

During FY 1998 the Rotorcraft program completed the development of rotor wake measurements systems and conducted measurements of rotor/fuselage interaction aerodynamic conditions for future validation of mathematical modules. A composite structures mathematical model was developed and experiments were conducted to validate prediction of fatigue life of thick composite structures. This work increased design accuracy and reduced the number of design iterations contributing to the goal of reduced design cost and time. This effort will contribute towards the goal of a 25% reduction in air travel costs, and reduced design cycle time. Tiltrotor wind tunnel tests continued for active control of aeroacoustics and performed work on active/passive noise and vibration reduction design techniques for conventional helicopters and tiltrotors. Supporting the aviation safety goals, improved performance with the use of drivetrain torque limit cueing provided by force feedback, based on neural network models derived from HUMS, was demonstrated in simulated flight. The results of this successful test were transitioned to the U.S. Army, the FAA, manufacturers, and logging operators. As a step toward making a flight-validated control-system design tool (CONDUIT) available to industry, Cooperative Research and Development Agreements (CRDAs) were established with 10 companies and a short course was offered that covered handling qualities, flight control, and modeling topics associated with the CONDUIT environment. Several analyses of the causes, consequences, and costs of helicopter accidents were completed: (1) a statistical analysis of "first events" codes in the NTSB database for the past 33 years; (2) a more detailed analysis of 1990-1996 accident causes and estimated costs; and (3) an in depth analysis of 34 representative fatal accidents performed by a government/industry team.

The latter identified the chain of events, problems, and suggested technology, procedural, training, and regulatory interventions that might prevent similar accidents in the future. These analyses resulted in a government/industry workshop focused on research areas likely have near-term payoff (e.g., improved training methods and materials and PC-based pre-flight planning and risk assessment systems) and will guide future safety investment decisions. In rotorcraft transmissions, the effect on life-limited components was evaluated using HUMS data from 1996 Olympics missions. The analysis demonstrated that usage tracking of life-limited components could lead to reduced operating costs and that certification data should be based on more maneuvers to improve flight condition recognition algorithms required for HUMS. In support of the overall goal of providing guidelines about crack propagation to support ultra-safe gear design, the effect of rim thickness on gear crack propagation path was investigated using finite element analysis, boundary element analysis, and fracture mechanics. This first phase validated the two-dimensional finite element/fracture mechanics crack-prediction capabilities. The National Rotorcraft Technology Center (NRTC) continues to concentrate on nearer-term needs and has applied 50-50 sharing of investments by industry and the U.S. Government (NASA and DOD) to develop rotorcraft technology ranging from rotor-noise reduction to ultra-safe transmissions. Other examples of responses to industry-wide needs included validated methods for science/computer-based design and cure control for thick composite structure. NRTC continued to further facilitate the design process through a cost-benefits algorithm developed with a newly available rotorcraft health-monitoring database.

In FY 1999, the Rotorcraft program will integrate new basic physics knowledge with advanced, information technology tools to provide accurate, flexible modules suitable for use by industry in their integrated design systems. A new emphasis aimed at thick composite structures will be undertaken to reduce parts count and the cost of rotorcraft. Noise reduction will encompass three areas: more effective noise reduction technologies for the rotor, both passive and active; additional attention to the active reduction of powertrain noise and vibration; and the continued assessment of operations that minimize noise impact on the ground, including the development of codes that can be used by community planners and airport operators. New innovative rotorcraft flight concepts will be actively supported through technical cooperation with DOD and industry. Testing of baseline rotorcraft helical gear train configurations, to establish minimum lubrication conditions while maintaining ultra-safe operations, will be completed.

Gear-crack propagation analysis tools, as well as specific gear experiments will be used to develop three dimensional (3D) boundary element/fracture mechanics analyses. Full-scale experiments will be used to validate conditions where two dimensional (2D) analyses is accurate and the technology will be transferred to industry via an ultra-safe transmission design-guide. Advanced control laws and modes designed to reduce pilot workload and increase safety in low-visibility conditions was developed using an integrated design tool (CONDUIT) and will be fight tested. The goal will be to achieve Level 1 handling quality ratings from pilots flying civil missions in the RASCAL UH-60. Expanding on the key findings of the accident analyses, new efforts will be initiated with helicopter operators and manufacturers to target near-term opportunities for accident reduction. A companion analysis of helicopter incidents will be completed.

In recognition of the critical role that loss of situation awareness has played in previous fatal accidents, methods of measuring and predicting situation awareness will be demonstrated in part-task simulation and efforts to improve detection and avoidance of obstacles, such as wires and poles, will be initiated. During its fourth year, the NRTC will continue to focus on nearer-term opportunities to reduce and improve performance and increase activities in flight safety and reliability. The NRTC will coordinate projects in conjunction with alliances among the FAA, DOD, NASA and industry to assess near-term national needs with a view to maximize leverage of the NASA investment while minimizing duplication. Completing the flight evaluation of Differential Global Positioning System (DGPS) coupled to heliport precision-instrument approach will enable a quantum improvement in integrating rotorcraft into the evolving transportation infrastructure. Demonstrating the structural characteristics of hybrid titanium/graphite-composite structures will provide for improved safety and affordability in engine compartments and other high temperature areas.

In FY 2000, the Rotorcraft program will conduct wind tunnel in conjunction with advanced active control research to reduce vibration, noise and improve performance. Building on the earlier fatigue life prediction of composite structure work, analytical and experimental techniques for tail rotor flexbeams will be established. Upon completion of evaluations of a number of innovative active and passive noise and vibration reduction concepts, the most promising techniques will be chosen for further research. Investigations to develop a fundamental understanding of gear-noise generation will begin and efforts to model the full flight vehicle for development of noise-abatement procedures will continue.

Accurate, flexible analysis modules suitable for use by industry in their integrated design systems will be completed. Rotorcraft safety will be emphasized through the development and evaluation of health and usage monitoring systems and predictive technologies. Methods of predicting and measuring pilot situation awareness will be developed and tested to allow designers the take this key factor into account when designing new systems. Using the situation awareness prediction model the effectiveness of new displays, and other pilot interface technologies for improving pilot situation awareness, will be demonstrated. Specifications for the hardware and format of a cockpit display designed to improve pilot situation awareness will be completed. The NRTC solutions of industry-wide problems will benefit the performance, utility and public acceptance of both helicopters and tilt-rotor concepts. The developed technologies will improve flight-safety with health-management systems, enhance design/manufacture compatibility, and alleviate both interior and exterior noise. Flight safety will be further enhanced through crashworthy design methodologies that account for landing on water or soft soil as well as on firmer surfaces. Proven application of active vibration alleviation with a horizontal-tail surface will provide reduced structure-borne loads and improved vehicle handling qualities.

BASIS OF FY 2000 FUNDING REQUIREMENT

CONSTRUCTION OF FACILITIES

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Replace Fan Blades, National Full-scale Aerodynamics Complex		2,000,000	(3,400,000*)
Replace Main Drive for 14x22 Foot Subsonic Tunnel		500.000	(7,300,000*)
Total		2,500,000	(10,700,000*)

* Funds for FY 2000 are included within other R&T Base elements.

A detailed description of these two program direct projects can be found within the MISSION SUPPORT CONSTRUCTION OF FACILITIES section.

BASIS OF FY 2000 FUNDING REQUIREMENT

AERONAUTICAL FOCUSED PROGRAMS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
High-Performance Computing and Communications	45,700	20,600	24,200
High-Speed Research	245,020	180,708	--
Advanced Subsonic Technology	144,400	89,600	--
Aviation System Capacity	*56,700	*53,900	60,000
Aviation Safety	--	--	60,000
Ultra Efficient Engine Technology	--	--	50,000
Total	491,820	344,808	194,200

*Previously budgeted within the Advanced Subsonic Technology Program

NASA's Aeronautics focused programs address selected national needs, clearly defined customer requirements and deliverables, critical program decision and completion dates, and a specified class of research with potential application. Each of the focused programs is discussed in detail on the following pages.

BASIS OF FY 2000 FUNDING REQUIREMENT

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
High-performance computing and communications............	45,700	20,600	24,200

PROGRAM GOALS

As a key participant of the Federal HPCC program, the primary purpose of NASA's HPCC program is to extend U. S. technological leadership in high-performance computing and communications by accelerating the development, application, and transfer of high-performance computing and communications technologies to meet the engineering and science needs of the U.S. aeronautics, Earth and space science, spaceborne research, and education communities, and to accelerate the distribution of these technologies to the American Public. As international competition intensifies and as scientists push back the frontiers of knowledge, leading-edge computational science is more important than ever. Studies have shown that high performance computing technologies have a significant positive impact on job creation, economic growth, national security, world leadership in science and engineering, health care, education, and environmental resource management. These technologies also enable the missions of many Federal agencies. The goals of the NASA High Performance Computing and Communications (HPCC) program are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the NASA stakeholders.

STRATEGY FOR ACHIEVING GOALS

The HPCC program goals are supported by these specific objectives:

1) Develop algorithm and architecture testbeds that are able to fully utilize high-performance computing and networking concepts and increase end-to-end performance.
2) Develop high-performance computing architectures scalable to sustained TeraFLOPS performance.
3) Develop high-performance networking architectures scalable to enable Gigabits per second aggregate applications traffic.
4) Demonstrate HPCC technologies on U.S. aeronautics, Earth and space science, and spaceborne community research problems.
5) Develop services, tools, and interfaces essential to the distribution of technologies to the American public.
6) Conduct pilot programs in education and the public use of remote sensing data that demonstrate innovative distribution of technologies to the American public.

The NASA HPCC program is currently structured to contribute to broad federal efforts while addressing agency-specific computational problems called Grand Challenges. Specifically, NASA provides resources to develop tools to solve Grand Challenges in five HPCC project areas: Computational Aerosciences (CAS), managed by the Office of Aero-Space Technology; Earth and Space Sciences (ESS), managed by the Office of Earth Science; Remote Exploration and Experimentation (REE), managed by the Office of Space Science; Learning Technologies (LT), managed by the Office of Human Resources and Education; and the NASA Research and Education Network (NREN), managed by the Office of Aero-Space Technology.

	FY 1998	FY 1999	FY 2000
Aero-Space Technology	45,700	20,600	24,200
Earth Science	18,300	14,500	21,900
Space Science	5,600	8,400	19,500
Education Programs	4,200	4,000	4,000
Total direct HPCC (NASA-wide)	73,800	47,500	69,600

The NASA HPCC program is planned and executed in cooperation with Federal agencies, industry, and academia to exchange information about technical and programmatic needs, issues, and trends. Interagency collaboration is fostered through the National Coordination Office which has a full time staff to support the main HPCC coordinating body--the Computing, Information, and Communication R&D Subcommittee (part of the National Science and Technology Council).

Interagency Cooperative Programs:

NSF/DARPA/NASA Digital Library Joint Research Initiative - The National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), and NASA jointly sponsor the Digital Library Joint Research Initiative in order to demonstrate technologies needed to build digital libraries to electronically access NASA science data. This multi-agency effort was initiated in FY 1994 and concluded in FY 1998. NASA, in conjunction with NSF and DARPA, co-funded six research and development projects.

NSF/NASA Distributed Computing – The National Science Foundation (NSF) and NASA are jointly sponsoring research in software technologies needed to manage and operate geographically distributed computing resources. This multi-agency effort was initiated in FY 1998 and represents a key component of an envisioned capability to utilize the nationwide supercomputing assets.

Next Generation Internet (NGI) - NASA is a participant in the multi-agency NGI effort that also includes the Departments of Defense, Energy, and Commerce, and the National Science Foundation. NGI builds on the base of current NASA Research and Education Network (NREN) R&D activities. NASA-sponsored research will focus on network performance measurement, network interoperability, quality of service and network security. NASA will continue to be an early adopter of emerging networking technologies that chart a course for a robust, scalable, shared infrastructure supporting lead users from NASA, the research community, and other government agencies.

National HPCC Software Exchange (NHSE) - The Federal HPCC agencies working in concert with academia and DoE laboratories developed a National HPCC Software Exchange to provide an infrastructure that encourages software reuse and the sharing of software modules across organizations through an interconnected set of software repositories. This multi-agency effort was initiated in FY 1992 and was concluded in FY 1998.

PetaFLOPS Initiative - The current Federal High Performance Computing and Communications Program is working toward achieving TeraFLOPS (one trillion floating operations per second) computing. However, experts in government, academia and industry have realized that capabilities beyond TeraFLOP-level computing systems will be required in the future. As a result, NASA, NSF, DoE, DARPA, National Security Agency, and the Ballistic Missile Defense Organization are developing technologies to support PetaFLOP (one million-billion floating operations per second) computing systems. The NASA HPCC Program, in coordination with the Information Technology Research and Technology Base Program, is providing "seed" funding in PetaFLOP computing architecture research.

The following discussion describes the projects managed by the Office of Aero-Space Technology.

Computational Aerosciences

The Computational Aerosciences (CAS) project is addressing the high-end computing needs of the aerospace community and has evolved during the course of the Project to support the development of the computing tools that the aerospace industry seeks. The CAS objectives are: to accelerate development and availability of high-performance computing technology of use to the U.S. aerospace community; to facilitate adoption and use of this technology by the U.S. aerospace industry; and to hasten emergence of a viable commercial market for hardware and software vendors to exploit this lead. CAS targets advances in aeroscience algorithms and applications, system software, and computing machinery that will enable more than 1000-fold increases in system performance early in the Twenty-first Century. These computational capabilities will be sufficiently characterized such that they can be rapidly integrated into economical design and development processes for use by U.S. industry. Although CAS does not develop production computing systems, CAS technology and the characterization of existing hardware and software will enable the development of full-scale systems by industry and will make commercial ventures into this area more attractive.

NASA Research and Education Network

The NASA Research and Education Network (NREN) project is extending U.S. technological leadership in computer communications through research and development that advances leading edge networking technology and services. NREN is NASA's part of the Federal Next Generation Internet (NGI) and serves the NASA community under the NGI umbrella. As part of the Federal Computing, Information, and Communications (CIC) R&D Large Scale Networking (LSN) Program, the main goal of NGI is to assure continuing U.S. technological leadership in communications through research and development that advances the leading edge of internetworking technologies and services. The Next Generation Internet initiative is a multi-agency Federal partnership with industry and academia to develop significantly higher performance networking technologies and systems enabling next-generation distributed applications between scientists, engineers, and computing resources. The NGI initiative connects universities and Federal research institutions with high-speed networks that are 100 to 1,000 times faster than today's Internet, promotes experimentation with the next generation of networking technologies, and demonstrates new applications that meet important national and agency goals.

SCHEDULE AND OUTPUTS

Install 100-250 **GigaFLOPS** sustained TeraFLOPS-scaleable testbed. Plan: June 1998 Actual October 1998	Install testbed and measure scalability and performance against success criteria. Delay due to availability of vendor hardware. A large-scale 256-processor ORIGIN2000 system manufactured by Silicon Graphics Inc. (SGI) has been acquired, installed and brought to operational testbed status. Over 100 GigaFLOPS has been demonstrated on industry-standard benchmark codes. In order to achieve this unique system, specific hardware and software was developed under a Memorandum of Understanding between NASA and SGI to combine two 128-processor machines into a larger single testbed
Demonstrate a portable, scaleable programming and runtime environment for Grand Challenge applications on a TeraFLOPS-scaleable system. Plan: September 1998 Actual September 1998	Demonstrate that applications scale logarithmically with the number of processors and are portable to all current testbeds. A runtime partners. In addition, specific runtime tools for code environment for the Numerical Propulsion Simulation System has been demonstrated and delivered to industry parallelization, debugging, job management, computing system management have been demonstrated on multiple computer testbeds.
Demonstrate 200-fold improvement over FY 92 baseline in time to solution for Grand Challenge application on TeraFLOP testbeds. Plan: June 1999	One application from each project in the selected test cases must scale logarithmically or better and have processor factor speed-up at least 50% of ideal, be portable to all testbeds, and perform at 200 times its current baseline.

Demonstrate 500 times end-to-end performance improvement of Grand Challenge and/or NASA mission applications based on FY 96 performance measurements across NASA NREN testbeds over 622 Mbps wide area network. Plan: September 1999 Revised March 2000	Performed at least three demonstrations at 500 times more end-to-end performance improvement over FY 96 baseline. Additional time is required to address the newly selected NASA applications.
Establish an international Next-Generation Internet eXchange (NGIX) Plan: January 2000	Demonstrate connectivity across an international Next-Generation Internet eXchange.
Demonstrate multicast and quality of service (QoS) technology in a hybrid networking environment Plan: June 2000	Provide at least two demonstrations of multicast and QoS technology in a hybrid (wireless and ground) networking environment.
Demonstrate time-to solution improvements for grand challenge applications on HPCC testbeds **Plan: September 2000**	**Demonstrate at least a 400-fold improvement over 1992 baseline in time-to-solution for one grand challenge application in the area of computational aerosciences.**

ACCOMPLISHMENTS AND PLANS

During FY 1998, the NASA HPCC Program's **Computational Aerosciences** (CAS) Project (in coordination with the Information Technology R&T Base Program) installed a computing testbed that will allow evaluation of prototype systems, subsystem interfaces and protocol standards. At the core of this newly installed testbed are two 128-processor and one 64-processor Silicon Graphics Inc. (SGI) ORIGIN 2000 machines installed at NASA Ames Research Center. Working closely with SGI under a Memorandum of Understanding (MOU), specialized hardware and software is being developed to link the two 128-processor machines together into a unique, 256-processor system capable of over 100 GigaFLOPS during benchmark execution. In cooperation with the Consolidated Supercomputing Management Office (CoSMO), an additional two 16-processor SGI ORIGIN 2000 systems were installed at NASA Langley and NASA Glenn Research Center to continue and extend the metacenter research that was started with the original IBM SP2 systems.

To provide an effective testbed system for Grand Challenge researchers, the CAS Project completed the development of key software tools for a portable, scalable programming and runtime environment. This environment was demonstrated with the Numerical Propulsion System Simulation (NPSS) and the National Cycle Program (NCP) efforts, an object-oriented framework for High-Speed Civil Transport (HSCT), work on legacy code migration, and the Parallel Graphics Library for 3-D visualization. Planning was started for development of a computational grid system (called Information Power Grid) -- an omnipresent hardware and software infrastructure that links computational resources in a seamless and reliable way.

The CAS Project also continued to make significant advances towards meeting the goal of 200-fold improvement in time-to-solution for Grand Challenge problems. Large-scale multidisciplinary simulations on representative high-speed civil transport and advanced subsonic aircraft continue to test the limits of modern parallel supercomputers while providing the pacing applications for further system software developments. The coupling of multidisciplinary tools within a collaborative environment is enabling complex propulsion system simulations and is on track towards meeting the goal of 24-hours turn around for full aircraft engine simulations.

Also in FY 1998, the **NASA Research and Education Network** (NREN) Project initiated its support of the federal Next Generation Internet (NGI) initiative. NREN installed high performance interconnections with the research networks of other federal agencies and conducted research into network quality of service issues and multicast scalability. During the year, the NREN Project designed and implemented Next Generation Internet Exchange–West (NGIX-West) and cooperated in establishing the NGIX-Mid America (NGIX-Mid). This activity demonstrated over 100-fold increases in capability to access NASA's high performance resources by Grand Challenge university researchers.

In FY 1999, the CAS objective is to improve the time-to-solution for Grand Challenge applications using a newly-installed TeraFLOPS testbed. CAS applications will meet the goal of performing at 200 times the established baselines. This will also be supported by NREN/NGI technologies through NREN goals of enabling network-intensive applications. NREN will address specific applications both relevant to NASA missions and providing the pacing requirements for further networking research and implementation.

While continuing to use high-end computing systems, CAS will begin more in-depth efforts to develop computational grids and will increase its work on computational grid concepts through expanded collaborations with academia, NSF, and DARPA. The prototyping of a computational grid will seamlessly link NASA resources—computers, data, instruments, and people—into an interdisciplinary problem-solving and decision-making environment. This effort is driven by: (1) NASA requirements to make more effective and coordinated use of existing and future computational assets, and (2) the need for collaboration among individual groups that are using advances in software technology to develop sophisticated problem solving systems. By recognizing the similarity in the underlying approaches to meeting these needs, an overall system can be developed that provides an improved environment for resource management, while at the same time providing a uniform architecture for software development—from systems software (including security, resource management, etc.) to the domain applications. During FY 1999, the focus of this effort is on demonstrating numerically-intensive applications on a set of distributed computer resources from both NASA and NSF.

In FY 2000, CAS will continue to improve time-to-solution for Grand Challenge applications while implementing initial software to demonstrate a prototype distributed high-performance testbed (computational grid). Along with the installation of HPCC's Earth and Space Science testbed, the CAS computational grid testbed will provide the vital computing resources required to achieve 1,000-fold improvements over established baselines. NREN will demonstrate applications that demand high-performance network capabilities, in some cases focusing its research on the same applications as CAS and ESS. NREN efforts will focus on the development and testing of mechanisms for scheduling guaranteed network quality of service to meet real-time bandwidth, latency and error tolerance requirements. This vital work supporting Next Generation Internet (NGI) will increase the quality, security and certainty of Internet transmissions and on the network capable of 1,000 times the capacity of the baseline.

BASIS OF FY 2000 FUNDING REQUIREMENT

HIGH-SPEED RESEARCH

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
High-speed research..	245,020	180,708	--

PROGRAM GOALS

Studies identified a substantial market for a future supersonic airliner — or High-Speed Civil Transport (HSCT) — to meet the rapidly growing demand for long-haul travel, particularly across the Pacific. This market could support 500 to 1,000 HSCT aircraft, creating a multi-billion dollar sales opportunity for its producers. Such an aircraft may be essential for capturing the valuable long-haul Pacific Rim market. Market studies indicate that the successful development of a domestic HSCT results in $200 billion in sales and 140,000 jobs for U. S. industry. As currently envisioned, an HSCT aircraft would carry 300 passengers at Mach 2.4 on transoceanic routes over distances up to 6,000 nautical miles at fares comparable to subsonic transports.

NASA has been developing the technologies that industry needs to design and build an environmentally compatible and economically competitive HSCT for the 21st century. The High-Speed Research (HSR) program goal was to have the technology available to enable an industry decision on aircraft production.

STRATEGY FOR ACHIEVING GOALS

In the early 1990's, studies indicated that an environmentally compatible and economically competitive HSCT could be possible through aggressive technology development. Since then, NASA concentrated its investments in the pre-competitive, high-risk technologies. While NASA has continued to be successful and is on track to meet the original program goals, recent market analyses and estimated industry development costs of $15 to $18 billion have made the HSCT considerably less attractive to NASA's industry partners. Cost of development in this amount puts the aircraft industry at significant financial risk. Current analyses indicate that further significant investments in technology development are required to ensure an economically viable HSCT. Consequently, the cost of development has led the major aircraft manufacturer to the conclusion that the introduction of an HSCT cannot reasonably occur prior to the year 2020. For these reasons, industry has reduced their commitment to this area and has scaled back their investments. Given other pressing needs in the Agency in general, and aeronautics in particular, the HSR program will be concluded by the end of FY 1999.

Since its inception, NASA's HSR program has made significant contributions to aeronautics state of the art. It has provided a public-sector catalyst in addressing this important opportunity with U. S. industry through a two-phase approach. The first phase, successfully completed in 1994, defined HSCT environmental compatibility requirements in the critical areas of atmospheric effects, community noise and sonic boom and several milestones—including completion of a preliminary noise assessment; selection of engine cycle, inlet, and nozzle concept; selection of candidate flight deck concepts; identification of preliminary wing and fuselage structural concepts; and, ultimately, definition of a technology concept—contributed to a technology foundation that provided confidence that the necessary technology could be developed. The second phase was a cooperative program with U. S. industry, directed at developing and validating designs, design methodologies and manufacturing process technology for subsequent application by industry in future HSCT aircraft programs to ensure environmental compatibility and economic viability. As HSR Phase II is concluded it will have exceeded the original HSR Phase II program goals planned through FY 1999 for environmental compatibility and economic viability. As an example of the highly successful nature of this program, the technology concept airplane (TCA) baseline defined in December 1998 is several decibels quieter than the original HSR noise goals. Accomplishments contributing to TCA definition include successful completion of subscale combustor tests and large-scale nozzle tests; selection of turbine airfoil alloy and turbomachinery disk material; selection of a combustor configuration; completion of wing and fuselage subcomponent tests; and completion and evaluation of supersonic laminar flow control tests.

Langley Research Center (LaRC), the lead center, was responsible for policy and program implementation, project planning and funding allocation, vehicle systems engineering and integration, and direct airframe contractor interface and management. At the NASA Aeronautics Centers (Ames Research Center (ARC), Dryden Flight Research Center (DFRC), LaRC and Glenn Research Center (GRC)), the Center Directors provide personnel and facilities to conduct research, analysis and program management in support of the program. GRC was also responsible for the propulsion contractor interface and management.

The team of primary HSR contractors consisted of airframe, propulsion system and advanced flight deck companies. These contractors were responsible for: the research, development and validation of specific technologies; the development and assessment of a next-generation High-Speed Civil Transport (HSCT) concept and configuration; the system-level integration of the advanced technologies being developed; and the conduct of associated tasks, such as mission analysis and database development. The primary propulsion contractors were the team of Pratt & Whitney and General Electric Aircraft Engines. The primary airframe contractor was Boeing. The advanced flight deck contractor was Honeywell International. ARC provided significant support directly to LaRC in advanced flight deck development, in computer modeling and simulation, and in economic analysis. DFRC provided support for flight-related activities. LaRC was responsible for integration of all elements of the program and GRC is responsible for propulsion systems technology integration.

The HSR program was enhanced by participation, in coordination and cooperative efforts to exchange information and data, with other NASA organizations and federal agencies that include:

- The Atmospheric Effects of Stratospheric Aircraft Panel, that includes participation by NASA's Office of Mission to Planet Earth, Environmental Protection Agency, Federal Aviation Administration, National Oceanic and Atmospheric Administration, National Science Foundation and Department of Defense. The panel provides guidance and evaluation of research related to the effects of high-speed civil transports on the upper atmosphere;

- The FAA/NASA Coordinating Committee provided the framework for developing and defining HSCT certification requirements; and
- The Department of Defense provided a cooperative forum for advanced engine technology development via its Integrated High Performance Turbine Engine Technology (IHPTET) initiative.

SCHEDULE AND OUTPUTS

Engine Static Test (Large Scale Model Build 1) Complete. Plan: March 1998 Actual: February 1998	Design, fabricate and test a 60 percent-scale nozzle model. Static performance and acoustic data will be collected. Enabling Propulsion Materials project will provide carbon matrix composites (CMC) liner panels and thermal protection system to be tested. The propulsion elements of the program were re-planned to provide better connectivity between materials and components and to improve the test plan to ensure that testing occurs at appropriate scales. Completed test and analysis of data gathered from 60 percent-scale model nozzle test. Aero-acoustic data calibrated prediction tools utilized for predicting large scale nozzle performance using small-scale nozzle data.
Combustor Configuration Selected. Plan: May 1998 Actual: May 1998	Combustor selection will be based on results of sector testing with advanced metallic and ceramic matrix composite liners, annular rig testing, manufacturing infrastructure assessment, analyses, and preliminary designs of the two most promising combustors. The subscale combustor annular rig tests will not be performed for the rich burn/quick quench/lean burn configuration prior to down- select. This was a result of a management assessment, which indicated that the data to be acquired would not impact the down-select. The Lean Premixed Prevaporized (LPP) concept was chosen based primarily upon ultra low levels of NOx achieved in subscale sector tests and no identified showstoppers from a potential product development path.

Preliminary Flight Deck Configuration Selected. Plan: July 1998 Actual: July 1998	Down-selection of preliminary flight deck configuration including: choice of control inceptor; selection of basic External Visibility System concept; evaluation of terminal area guidance and control concepts; development of decision-aiding concepts; confirmation of flight deck design and automation philosophy; and provision of both electronic and physical cockpit mock-ups.
Subcomponent Test Articles. Plan: September 1998 Actual: October 1998	Delivery and preparation of several wing and fuselage subcomponent articles for structural testing. All wing and fuselage subcomponents have been designed, fabricated and prepared for structural testing.
Subcomponent Test Data (Materials and Structures). Plan: September 1998 Revised: March 1999	Release of data acquired during static and damage-tolerant testing of wing and fuselage subcomponent articles. All data acquired during wing subcomponent testing and during five of seven fuselage subcomponent tests compiled and released. Remaining two fuselage subcomponents will be tested and data released by end of March 1999.
Component Materials Selection. Plan: September 1998 Revised: March 1999	Materials and structural (M&S) concepts will be selected for wing and fuselage component test articles. Selections will be based on material performance, structural efficiency, and production costs as determined by testing and analytical studies. M&S concepts have been selected for wing component test article; M&S concepts for fuselage component test articles will be selected in March 1999. Selections are based on material performance and structural efficiency and uses analyses and test data.
Phase II Assessment of Atmospheric Impact. Plan: September 1998 Revised: February 1999	Complete the assessment of environmental compatibility of HSCT incorporating HSR emissions reduction technology. Draft report complete; late breaking data from field observations and model findings are being incorporated prior to publication of the report.
Technology Configuration Defined. Plan: December 1998 Actual: December 1998	Define an optimized NASA/Industry technology baseline airplane configuration resulting from HSR technology validation development and down-selection processes. Make final selection of technology elements for the airplane and embody these features in the baseline airplane. An HSR Technology Configuration baseline airplane was defined that met or exceeded all exit criteria using HSR technology expected from Phase II.

Full Scale Design Build 1 Designed; Configuration/Materials (Decision). Plan: June 1999 Revised: March 1999	Complete preliminary and detailed design of a full-scale actuated nozzle. Configuration and component material selections determined. Due to program termination, the nozzle design effect will be terminated after the Conceptual Design Review (CDR) scheduled for March 1999. The preliminary and detailed design efforts will not be initiated nor completed.
1-Lifetime Accelerated Test Data. Plan: June 1999	Initial release of 1-lifetime of data acquired during accelerated thermal-mechanical-fatigue testing of materials; for use in validating analytical methods for predicting material degradation.
Full Scale Annular Combustor, Rig, and Liner Design - Configuration/Materials Plan: September 1999 Actual: February 1999	Complete detailed design of the selected HSCT scale combustor and life prediction analysis for the liner. Design temperatures and stresses in the liner are within the capabilities of the EPM developed material. Drawings are released for fabrication. Due to re-planning for termination of this program, the work toward this milestone will cease and no detailed design effort (or associated efforts such as life prediction) will be completed and no interim products will be available.
Program Technologies Documented Plan: September 1999	In-depth documentation of HSR Phase II technologies incorporated in the HSR Technology Concept Level 1 milestone of December 1998 will be completed along with a concise summary of lessons learned in HSR work. Technology advances achieved in the HSR program will be appropriately integrated into ongoing and planned NASA programs where data restrictions allow.

ACCOMPLISHMENTS AND PLANS

During FY 1998, the HSR program continued developing the technology database to raise the Technology Readiness Levels from 2-3 (technology concept formulated/proof of concept) to 3-4 (proof of concept/component test in laboratory environment). The Tu-144 flight testing was completed, and experimental data reduced, analyzed and compared with HSCT design tools. Analytical methods for accelerating the combined thermal-mechanical-fatigue testing to match real-time degradation parameters for composite and metallic materials were released. The HSR simulator cab was integrated on the Langley Research Center Cockpit Motion Facility. Potential flight deck concepts were installed, including strategic and tactical flight path management, external visibility system display design, and center stick control inceptor, and initial evaluations conducted. These data are being utilized to update the flight deck technology configuration benchmark report and 3D electronic benchmark configuration model. Benchmark concepts include those for a functionally integrated flight deck configuration, an external vision system, control laws and flight controller, flight path management (strategic and tactical), crew interaction with automation, crew autoflight integration, multi-function displays/controls, and management of non-normal situations. Design, fabrication and testing of a 60 percent-scale nozzle model was performed to obtain static performance and acoustic data. Ceramic matrix composite liner panels and thermal protection system were also tested. Emissions, performance, material durability and operability testing of subscale lean and rich combustor sector at simulated cruise and landing and take-off conditions were completed on subscale test rigs. A combustor design was selected based on results of sector testing with advanced metallic and ceramic matrix composite liners, manufacturing infrastructure assessment, analyses, and preliminary designs of the two most promising combustors. The aeroelastic characteristics of the technology concept airplane design were optimized using multidisciplinary optimization for structures, aerodynamics, propulsion, and controls employing detailed finite element and computational fluid dynamic tools. Several wing and fuselage subcomponent articles were tested and correlated to analysis predictions. The engine concept technical readiness was reassessed using systems analyses that capture small-scale test results and analysis, material feasibility and manufacturing infrastructure.

As part of a planned orderly closeout at the end of FY 1999, the following activities will be concluded: Complete TIFS flight tests for external vision validation and validate a display, guidance, and control system. Complete airframe materials durability composite database under isothermal without load, complete all subcomponent testing and analysis and thermomechanical fatigue tests of thick laminate joints. Complete interim fabrication database of PETI-5. Complete half-span aeroelastic test in LaRC Transonic Dynamics Tunnel. Complete high-lift configuration evaluation. Complete high-speed performance validation. Complete an assessment of the environmental compatibility of the HSCT incorporating new emissions reduction technology. Complete design and fabrication of full-scale combustor sector rig. Complete combustion environment testing of Ceramic Matrix Composite (CMC) liner parts for ultra low emissions combustor. Compete conceptual design of full scale technology demonstrator nozzle. Complete initial assessments of innovative ultra low noise nozzle concept. Provide improved aeroacoustic scaling methodologies. Complete initial assessment of "waverider " inlet concept. Complete fabrication of subscale fan-inlet acoustics test rig. Complete scale-up feasibility effects of nozzle advanced materials (superalloy). Complete nozzle materials characterization studies. Complete down-selection process for turbomachinery disk and turbine alloy materials. Complete a technology identification study to meet new requirements for "Lessons Learned" documentation. Complete summary and lessons learned documentation for all technology areas for transfer, as appropriate, to other focused programs and base activities.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED SUBSONIC TECHNOLOGY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Advanced subsonic technology	*144,400	*89,600	--

*Capacity had previously been included within the Advanced Subsonic Technology Program and is now identified as a separate focused program.

PROGRAM GOALS

With competition from foreign competitors greatly increasing, affordable, innovative technology is critically needed to help preserve the U.S. aeronautics industry market share, jobs, and balance of trade. Exports in large commercial transports make a significant contribution to the U.S. balance of trade. However, according to industry estimates, the U.S. worldwide market share has slipped from a high of 91 percent during the 1960's to less than 67 percent today. Increasing congestion in the aviation system and growing concerns about the environmental compatibility of aircraft may limit the projected growth and more stringent noise-based restrictions and engine emissions standards are expected in the near future.

In addition, state government and corporate leaders recognize the vital importance of the infrastructure of small airports across the Nation that provides access for suburban, rural and remote communities to the national air transportation system. Accordingly, planning has been initiated, with the FAA, for a Small Aircraft Transportation System (SATS) technology development and deployment effort. The results of the current NASA general aviation investments create the basis for revolutionary new small aircraft and pilot training capabilities for business and personal transportation. This new generation of aircraft (as well as retrofit of the new technologies to the current fleet) sets the stage for national strategies and investments in "smart" operational capabilities and airports for the SATS.

The goal of NASA's Advanced Subsonic Technology (AST) program was to develop high-payoff technologies, in cooperation with the Federal Aviation Administration (FAA), the U.S. aeronautics industry and academia, to benefit the civil aviation industry's international competitiveness and the public. These technologies were aimed at reducing travel costs while increasing safety, reducing civil aircraft impact on the environment, and increasing doorstep-to-destination travel speeds. The success of the AST program has resulted in significant contributions to technology readiness that will preserve our Nation's economic health and the welfare of the traveling public, and mobility and accessibility to more destinations in the national air transportation system.

STRATEGY FOR ACHIEVING GOALS

The AST program was planned and designed to develop, in partnership with the FAA, the U.S. aeronautics industry and universities, high-payoff, high-risk technologies to enable a safe, highly productive global air transportation system that includes a new generation of environmentally compatible, operationally efficient U.S. subsonic aircraft. The critical needs were selected on the basis of industry/FAA technology requirements to provide a focused and balanced foundation for U.S. leadership in aircraft manufacturing, aviation system safety, and protection of the environment.

The development of these technologies has been an important step in accomplishing the enabling technology goals of the Enterprise's ***Global Civil Aviation*** and ***Revolutionary Technology Leaps*** Pillars. The projects of the AST program are aligned within the following four major thrusts that are consistent with the Enterprise goals defined under the two pillars: Safety, the Aging Aircraft project; **Environment**, including the Noise Reduction, Environmental Assessment and Emissions Reduction projects; **Reduced Seat Cost**, including the Airframe Methods and Design Environment Integration, Systems Evaluation, Airframe Materials and Structures and Engine Systems projects; and **General Aviation**.

Due to other pressing Agency needs in general and aeronautics needs in particular, the AST program will be concluded in FY 1999. Aggressive technology transition plans were pursued in order to mitigate the significant risk to successful technology transfer to industry as a result of early termination. Budgetary constraints notwithstanding, the AST program has been successful and progress was made toward meeting the current program goals.

Safety

With pressures on the bottom line, airlines are continuing to fly their aircraft beyond the typical design life of 20 years, or approximately 60,000 flight hours. Today, the average age of the world's operating fleet is over 12 years old, and approximately 1000 airplanes, or one-fourth of the operating fleet, is more than 20 years old. More than 500 of those airplanes are 25 years or older, and some airlines are planning to keep their airplanes flying past 30 years. This trend, simply based on the lower cost of inspection and maintenance versus the cost of acquiring new airplanes, will continue in the future as airlines attempt to attain positive balance sheets. However, the current inspection techniques are based largely on visual methods supported by single point measurements. Due to the reliance on human inspection, the results are subjective and as the airplanes age, inspection becomes more time consuming and costly. Methods for predicting the residual strength remaining in aging aircraft and cost-effective, broad-area nondestructive evaluation methods have been developed to reduce cost and time and eliminate error.

Environment

Aircraft noise is an issue, both nationally and internationally, prompting airports to operate with strict noise budgets and curfews that restrict airline operations. International treaty organizations are actively considering more stringent noise standards that will impact the growth of the aerospace industry. Noise curfews and inefficient noise abatement terminal area procedures exacerbate congestion. In 1969, the FAA issued Federal Aviation Regulation, Part 36 (FAR 36) to prevent the increase in noise produced by transport aircraft. In addition, concern for local noise impact issues often delays, and is sometimes the reason for not pursuing needed airport capacity improvements. In 1991, the FAA took an additional step by requiring that all Stage 2 aircraft be phased out by the year 2000. It is unlikely that the environmental community will tolerate increased overall noise levels due to growth in the number and size of new aircraft after the year 2000. The Noise Reduction project, in cooperation with U.S. industry and the FAA, targeted technologies to reduce, by the year 2000, the community noise impact for future subsonic transports by ten decibels (dB) relative to the 1992 state-of-the-art. The approach was designed to develop noise reduction technology for engine source noise, nacelle aeroacoustics, engine/airframe integration, interior noise, and flight procedures to reduce airport community noise impact, while maintaining high efficiency, with objectives achieved via systematic development and validation of noise reduction technology. The timing of the technology development was consistent with the anticipated timing of recommendations for increased stringency. Fundamental work in this area will transfer to the Airframe Systems program to reach the ten decibel goal planned for the AST program.

Propulsion emissions has gained significant visibility in international organizations, such as the International Civil Aviation Organization (ICAO), Committee on Aviation Environmental Protection (CAEP). These organizations are considering more stringent standards for engine emissions during landing and takeoff operations—i.e., below 900 meters altitude—as well as new standards for cruise operations. In the past, new combustor concepts and technologies have produced cleaner burning engines to offset the negative trends of more fuel efficient, higher pressure ratio engines. Additional new combustion concepts and technologies, including new improved fuel injectors and higher temperature liner materials, will be required to meet more stringent standards. In cooperation with the U.S. industry, NASA developed low emission combustor technology with the objective of reducing the environmental impact of future engines through reduced engine emissions. The goals of the Emissions Reduction project were to reduce nitrogen oxide emissions, by at least a factor of two or 50 percent within seven years, and a factor of three or 70 percent within ten years for both large engines and regional engines relative to the 1996 ICAO Standards. Research and development focussed on low emission combustors to be incorporated into the next generation of very-high-bypass ratio engines and derivatives, or enhancements of engines currently in service. Key technology development required for an ultra-efficient engine in the areas of propulsion emissions and environmental assessment will be transferred to the Ultra-Efficient Engine Technology program.

Environmental Assessment develops a scientific basis for assessing the atmospheric impact of subsonic commercial aircraft. The goals were to determine the current and future impact of aviation on the atmosphere and to provide scientific assessments of global ozone perturbations and climate change. Overall program direction and selection of investigators was guided by an advisory panel comprised of respected members of the scientific and aviation communities. Elements of atmospheric research (e.g., modeling, laboratory studies, and atmospheric observations) were complemented by studies unique to the aviation problem (engine exhaust characterization, near-field interactions, and operational scenarios). Current scientific understanding of aircraft effects was published in the IPCC Special Report: Aviation and the Global Atmosphere, and AST-sponsored research scientists made a substantial contribution to this report which focuses on subsonic aviation.

Reduced Seat Cost

To insure that the increased air travel requirements predicted for the 21st Century can be adequately satisfied by the U.S.-built aircraft, the focus of the Reduced Seat Cost thrust was to develop and validate aggressive technologies that significantly advance the state of the art in transport aircraft design and production. In order to realize this potential, the goal for the Airframe Methods and Design Environment Integration project was to enhance delivery of integrated design methodologies, new aerodynamic concepts, and faster design cycles. These concepts and tools provide superior aircraft and improved market responsiveness while reducing operating and ownership costs, environmental impacts, and aircraft development risks. As a result of early termination and final year budget reductions, the resultant technical objective is a demonstration by the U.S. transport aircraft industry that deliverables will provide a one- to two-percent reduction in aircraft direct operating costs (DOC) compared to 1995 baseline technology levels, and a 15- to 25-percent reduction in aerodynamic design cycle time over 1995 practices.

Another vital project, Airframe Materials and Structures, was aimed at gaining significant improvements in efficiency of transport aircraft while reducing costs. The goal of this project was to develop and validate innovative fabrication methods and models that offer a paradigm shift in robust, lightweight composite airframes. The primary technical objectives were verification of a composite structure wing design that costs 10 to 20 percent less to acquire and weighs 10 to 30 percent less than an aluminum aircraft sized for the same payload and mission. Significant cost savings are attributed to reducing part count with composite structural concepts and using revolutionary automated fabrication methods. This equates to potential savings in aircraft DOC of five percent. As a result of early termination and budget reductions in FY 1999, methods were validated and verified using one large-scale semispan wing test article.

In order to realize the full potential for propulsion capabilities, the goal of the Engine Systems project was to develop highly fuel efficient, maintainable, reliable and fault tolerant technologies and design methodology which meets the performance, emissions (including carbon dioxide) and safety requirements for the next generation of air transport systems. The goal of the project was to reduce the engine design and development cycle time. Aerodynamic, aeroelastic, and cooling (heat transfer) analytical models and computational tools were developed and validated using affordable advanced turbomachinery components (which are expected to result in a 30-percent reduction in design and development cycle time and engine testing). Research and development focussed on affordable advanced turbomachinery; high-temperature disk and blade materials; improved controls and accessories; advanced propulsion mechanical components; and lightweight, affordable engine static structures. The products of this project will be incorporated into the next generation of very-high-bypass ratio commercial engines and derivatives, or enhancements of engines currently in service, and technology development will transition to the new Ultra-Efficient Engine Technology program.

Finally, the Systems Evaluation project allowed for a full understanding of the relative payoff of emerging technologies. This project provided a systems analysis capability that is essential in the development of a credible assessment of the impact of NASA aeronautics technologies on the U.S. industry. The goal of this project was to provide credible assessments of the impact of alternative emerging civil aeronautics technologies on the integrated aviation system. Such assessments assist in planning new initiatives, as well as assist customers of AST technologies in understanding the impact and potential on an integrated aircraft and system. To better assess aeronautics technologies, an aviation system assessment capability (ASAC) linking the multidisciplinary and multifaceted aspects of the global aviation system was developed. This is significantly beyond the capabilities of any single analytical tool available today, though many of its constituent components exist in specialized areas, such as air traffic management.

General Aviation

General aviation in the U.S. represents approximately one-third of the nine and one half billion air miles flown by all civil aviation annually; about two-thirds of these hours are "commercial" or revenue-generating operations. In addition, roughly 90 percent of all airports in the U.S. are available exclusively for general aviation, and it accounts for about 40 percent of all instrument operations at towered airports. However, during the 1980's and early 90's, annual U.S. production of general aviation aircraft fell to less than five percent of the 1978 level and the infrastructure of small airports began to deteriorate. In partnership with U.S. industry, the FAA and universities, through a 50/50 cost-share joint venture, NASA established the Advanced General Aviation Transport Experiments (AGATE) Alliance. The goal of the Alliance is to support revitalization of U.S. general aviation through development and deployment of advanced avionics, airframe, pilot training, and engine-related technologies, creating the basis for a SATS. Improvements in safety, affordability, utility, ease-of-use, and reliability of the next generation of general aviation aircraft for business and personal transportation result from the application of these technologies. In the process, small aircraft transportation expands the mobility and accessibility of the Nation's smaller communities within the national air transportation system. Achieving the goal supports the expansion of the Nation's economy by better serving the vast infrastructure of over 18,000 general aviation landing facilities, which includes 5,400 public-use facilities. This expanded use of general aviation is expected to fuel expansion of the national economy by bringing the "off-airways" communities into the mainstream of U.S. commerce. In addition, SATS can help mitigate the pressure on capacity for the hub-spoke airport system as well as on demand for additional lane-miles of highway infrastructure.

SCHEDULE AND OUTPUTS

Safety

Complete field demos for tech transfer to industry	Complete field demonstrations to illustrate technology utilization and conduct focused workshops to transfer all technology to the instrument manufacturing industrial community.
Plan: September 1998 Actual: September 1998	Final milestone for this project. New analysis methodologies, in the form of structural integrity analysis computer codes, have been developed, experimentally verified, and are now in use by all U.S. airframe manufacturers. An Engineering Handbook describing the methodology, and including the computer codes and experimental data, is available on the web at http://irwin.larc.nasa.gov/handbook/index.html. Nondestructive inspection devices have been developed for disbond, corrosion, and crack detection that have resulted in commercial product licensing agreements.

Environment

Emissions Reduction: Evaluate flametube combustor concepts Plan: March 1998 Actual: December 1997	Advanced flametube combustor concepts will be evaluated for their potential to reduce NOx by conducting flametube experimental tests at 50 atmospheres to simulate engine combustor operating conditions. Advanced low NOx combustor concepts demonstrated 50-percent reduction in flametube tests and showed promise for achieving the 70-percent NOx reduction goal. As a result of refocusing, low emission combustor development transitioned from fundamental flametube testing to sector combustor testing 50-percent reduction fuel injectors (a more relevant environment) and allowed early completion of this work.
Noise Reduction: Demonstrate flight-applicable active noise control on large engine. Plan: December 1998 Deleted	Demonstrate that active noise reduction technology is sufficiently mature for flight application on a large engine. In response to industry input, the active noise control work was re-planned and, as a result, the decision was made to concentrate future active noise control work on the fan blade passage frequency tone.
Emissions Reduction: Demonstrate reduction of future large engine emissions of NOx by 50 percent. Plan: September 1999	Demonstrate in a full annular combustor rig a low emission combustor that meets the 50 percent NOx goal for large engines.
Environmental Assessment: UNEP/WMO Ozone/IPCC climate reports input. Plan: September 1999	Provide input for preparation of United National Environmental Panel (UNEP)/World Meteorological Organization (WMO) ozone and Intergovernmental Panel on Climate Change (IPCC) climate assessment reports.

Reduced Seat Cost

Systems Evaluation: Release second generation ASAC. Plan: March 1998 Actual: March 1998	An enhanced Web-based aviation analysis system with integrated model architecture and advanced system models and databases was delivered which provides the assessment of potential technology benefits.

Airframe Materials and Structures: Conduct semispan wing test. Plan: September 1998 Correction:September 1999	In-house semispan wing test conducted to provide critical assessment of revolutionary fabrication methodology and verification of analytical models to provide verification of analysis methodology, and cost and weight reduction data. (Milestone date was incorrectly reported in FY 1999 narrative.) Final milestone for this project.
Engine Systems: Demonstrate improved turbomachinery design. Plan: September 1999	Initial turbomachinery design tools and methods available for validation and application to next generation of highly fuel efficient, environmentally compatible, maintainable and reliable engine systems. Final milestone for this project.
Systems Evaluation: Release final ASAC. Plan: September 1999	Deliver the final functionally validated Web-based aviation analysis system with integrated model architecture and advanced system models and databases will be delivered which will provide the assessment of potential technology benefits. Final milestone for this project.
Airframe Methods: Three-dimensional high-lift analysis methods validated. Plan: September 1999	Calibrated three-dimensional Navier-Stokes methodology that allows for the analysis of subsonic transport configurations including simulation of the propulsion system power effects. Final milestone for this project.
General Aviation	
Complete market assessments. Plan: March 1999	Complete market assessments of current and latent market and assess domestic and international benefits.

ACCOMPLISHMENTS AND PLANS

FY 1998: $144.4 million

In **Safety**, the Aging Aircraft project was successfully completed with the development and commercialization of nondestructive prototype systems for disbond, corrosion and crack detection, and the transfer to the FAA, DOD and industry of verified structural integrity analysis methodology for predicting the onset of widespread fatigue damage, fatigue crack growth, and residual strength of fuselage structure.

In **Environment**, active control technology was validated to reduce engine fan tones in two laboratory, high-fidelity engine simulator tests. Concepts were discovered, optimized and validated at model scale to reduce flap and slat airframe noise sources. A flight test on a twin engine turboprop commuter airplane verified an active structural interior noise reduction concept to control interior propeller tone noise levels. Sector rig tests with advanced low NOx combustor concepts were conducted which demonstrated 50 percent NOx reduction levels. Subsonic Assessment (SASS) completed the second field campaign with the NASA DC-8 flying laboratory. The Subsonic Assessment Ozone and Nitrogen Experiment (SONEX) field campaign was the first attempt to measure subsonic aircraft emission signatures in the North Atlantic flight corridor. SONEX successfully measured a significant NOx and particulate aircraft fingerprint within these flight corridors. The environmental impacts of the current and future subsonic fleet are potentially significant. Current scientific understanding of critical atmospheric processes and the capability of predictive models are adequate only for qualitative assessment of aircraft effects in most areas. Substantial improvements are required in scientific understanding and atmospheric process models to provide quantitative impacts of aviation on the atmosphere. SASS-sponsored research scientists made a substantial contribution to the Intergovernmental Panel on Climate Change (IPCC) Special Report: Aviation and the Global Atmosphere planned for publication in 1999.

In **Reduced Seat Cost**, extended-use disk manufacturing concept was demonstrated to reduce cost by extending engine disk life and maintenance intervals. The final design for the composite semispan wing was updated based upon completion of the subcomponent testing, and the first-ever full-size cover panels utilizing revolutionary stitched composite technology were successfully fabricated for the semispan test article. The technology showed significant cost and time reductions were feasible with the innovative techniques. New, novel computational methods demonstrated a six-fold reduction in design cycle time through automation of high-lift design and analytical methods. An enhanced second generation ASAC was released and utilized by NASA and industry to assess advanced technology impact in the areas of safety, air carrier operations, noise and National Airspace System.

In **General Aviation**, with the definition of system requirements in place, development continued in the technology areas of ice protection, propulsion sensors and controls, human factors for flat-panel displays, COTS-based avionics computer hardware and software, composite materials manufacturing processes, crashworthiness, and digital data link communications systems standards. Additionally, assessments of U.S. and international general aviation markets began to evaluate the potential levels of growth in general aviation. The first students graduated from the AGATE unified instrument-private pilot curriculum with significant savings in cost and time to receive an Instrument Flight Rules pilot certificate. Two new airframe manufacturing partners in AGATE successfully certified the first new general aviation single-engine aircraft in over 16 years, incorporating several NASA and AGATE-derived technologies.

FY 1999: $89.6 million

In **Environment**, an improved and updated community noise impact model to include noise impact minimized flight tracks will be completed and released. Full-scale, static engine demonstrations of advanced engine and nacelle noise reduction concepts will be conducted. Broadband engine fan noise will be investigated in a model-scale, wind tunnel experiment. Sector and full annular testing of low emission combustor concepts will be conducted which will meet the 50-percent NOx reduction goal for large engines. SASS will conduct the Atmospheric Chemistry of Combustion Emissions Near the Tropopause (ACCENT) field mission to further characterize aircraft particle contributions at the regional scale, particularly as they affect cloud nucleating properties of the atmospheric aerosols. Current scientific understanding of aircraft effects will be published in the IPCC Special Report: Aviation and the Global Atmosphere. SASS-sponsored research scientists made a substantial contribution to this report which focuses on subsonic aviation.

In FY 1999, efforts supporting **Reduced Seat Cost** will be completed. Improved turbomachinery design codes will be applied and validated to demonstrate increased capability (highly efficient, environmentally compatible and reliable) engine systems. Testing of the semispan advanced composite wing will be conducted to verify weight (25 percent reduction) and structural performance goals, and wing cover panels will be fabricated to verify the cost reduction goal (20 percent reduction). An analysis method for an integrated aerodynamic design of the wing with the propulsion system will be validated and provided to industry to contribute to a reduced design cycle time. Following completion of evaluations of the earlier release, the operational version of the ASAC computer code, including aviation databases and economic and aviation system analysis models, will be released to complete the Systems Evaluation project.

In **General Aviation**, work will be completed in ice protection and propulsion sensors and controls. The assessments of current and latent general aviation markets will be conducted. The AGATE "highway-in-the-sky" operating capability will begin final development, with the planned certification issues resolution for COTS-based avionics and display hardware and software architecture for the cockpit. Flight training learning modules will be developed for next generation AGATE cockpit systems. Design and manufacturing technology development will continue toward crashworthy composite airframes, including airbags.

BASIS OF FY 2000 FUNDING REQUIREMENT

AVIATION SYSTEMS CAPACITY

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Aviation Systems Capacity	*56,700	*53,900	60,000

*Previously included as a project within the Advanced Subsonic Technology Program

PROGRAM GOALS

In FY 2000, the Capacity project of the Advanced Subsonic Transportation (AST) program will be separated from the AST program and designated a separate program called Aviation Systems Capacity (ASC).

According to airline representatives, delays in the Air Traffic Control System cost U. S. operators approximately $3.5 billion per year in excess fuel burned and additional operational costs. The number of airports experiencing 20,000 hours of delay each year is projected to increase by 50 percent by 2003. Due to environmental issues and cost, only one major new U. S. airport—in Denver—will be opened this decade. With little ability to build new or expand current airports in the populated areas where they are needed, airport delays will continue to grow. More efficient and flexible routing, scheduling, and sequencing of aircraft in all weather conditions is critical to meeting capacity demands. The U. S. aviation industry is investing $6 billion over 20 years to increase airport capacity. However, a gap still exists between the industry's desired capacity and the ability of the National Airspace System to handle the increased air traffic. Another part of the solution to capacity demands is to off-load the major airports by developing short-haul routes among the 5200 public-use airports available throughout the country. Studies conducted by Boeing Commercial Aircraft for NASA and the FAA and by various state and local transportation authorities (e.g., Port of New York and New Jersey Authority) have shown the civil tiltrotor to be a viable candidate for relief of air traffic congestion.

The ASC program supports on the Enterprise's Global Civil Aviation goal of "tripling the aviation system throughput in all weather conditions, within 10 years, while maintaining safety". The goal of the Aviation System Capacity (ASC) program is to enable safe increases in the capacity of major US and International Airports through both modernization and improvements in the Air Traffic Management System and the introduction of new vehicle classes which can potentially reduce congestion, specifically: to increase National Airspace System (NAS) throughput while assuring no degradation to safety or the environment; to increase the flexibility and efficiency of operations within the NAS for all users of aircraft, airports and airspace; and to reduce system inefficiencies.

STRATEGY FOR ACHIEVING GOALS The ASC program is composed of the Terminal Area Productivity (TAP), Advanced Air Transportation Technology (AATT), and the Civil Tiltrotor (CTR) projects. The TAP project develops technology and procedures to support the aviation systems infrastructure by reducing system delays and enabling new modes of airport operation to support "Free Flight". The AATT project develops decision making technologies and procedures to provide all airspace users with more flexibility and efficiency, as well as enable new modes of operation that support the FAA commitment to "Free Flight". The CTR project develops technologies and procedures to overcome inhibitors to a civil tiltrotor operating within an improving and modernized air traffic system. The ASC program works closely with manufacturers, the airlines and the FAA, the technology customers, who are responsible for applying the candidate technologies as operational systems.

In the area of Air Traffic Management R&D, NASA and the FAA have an integrated research and technology development plan, approved by both the NASA Associate Administrator for Aero-Space Technology and the FAA Associate Administrator for Research and Acquisition. An Inter-Agency Integrated Product Team (IAIPT) is responsible for the strategic management of this area of research by the FAA and NASA, assuring that the efforts of both agencies are conducted to maximize the benefits of the research. The IAIPT reports to a NASA/FAA Executive Council, comprised of the appropriate Associate Administrators from both Agencies. Each agency is responsible for the conduct of its Programs. Oversight of the NASA Programs is provided through the NASA Advisory Council. The Ames Research Center is the lead center for the program and each of the three current projects, with the Langley and Glenn Research Centers providing supporting research.

The **Terminal Area Productivity** (TAP) project is focused on increasing capacity at airports. The objective is to provide technologies and operating procedures enabling productivity of the airport terminal area in instrument-weather conditions to safely match that in clear-weather or visual conditions. In cooperation with the FAA, NASA's approach in TAP is to develop and demonstrate airborne and ground technology and procedures to safely reduce aircraft spacing in the terminal area, enhance air traffic management (ATM) and reduce controller workload, improve low-visibility landing and surface operations, and to integrate aircraft and air traffic systems to address the problems described above. By the end of the decade, integrated ground and airborne technology will safely reduce spacing inefficiencies associated with single runway operations as well as the required spacing for independent, multiple runway operations conducted under instrument flight rules. Single runway operations are expected to increase by at least 12 to 15 percent under instrument weather conditions. Given the capabilities of future air traffic control automation and improved wake vortex knowledge, "dynamic spacing" between pairs of aircraft types in the landing sequence for a given airport runway system is possible and desirable for maximum safety, capacity and efficiency.

The goal of the **Advanced Air Transportation Technology** (AATT) project is developing technologies to enable the next generation of increases in capacity, flexibility and efficiency, while maintaining safety and not degrading the environment, of aircraft operations within the U. S. and global aviation system. In alignment with the national consensus for the operating paradigm of the future, called "free flight", the technical objective is to provide human-centered, error-tolerant automation to assist in short- and intermediate-term decision-making among pilots, controllers and dispatchers to integrate block-to-block planning services. This will allow all airspace users to choose the best flight path for their own purposes within the constraints of safety and the needs of other users. Specific objectives include: (1) enabling "free flight" to the maximum possible degree to allow users to maximize business/customer impacts by making trade-offs between time and routing; (2) improving the effectiveness of high-density operations in regions on the ground and in the air where free flight will not be possible, and (3) enabling operation in a smooth and efficient manner across boundaries of free flight and capacity-constrained flight regions.

While the tiltrotor has been shown to be a viable military aircraft (V-22 Osprey), insufficient research has been undertaken on technologies critical to civil applications such as noise, terminal area operations, safety, passenger acceptance, weight reduction, and reliability. The **Civil Tiltrotor (CTR)** project focuses on noise reduction; cockpit technology for safe, efficient terminal area operations; and contingency power. To achieve acceptable levels of external noise in the terminal area, prop-rotor noise must be reduced by six decibels A-weighted (dBA) over current technology. Complex flight profiles involving steep approach angles and multi-segmented approach paths will be developed to provide an additional six dBA reduction. To enable these approaches to be safely flown under all weather conditions, integrated and automated control laws and displays will be developed.

SCHEDULE AND OUTPUTS

Terminal Area Productivity:

Transport system research vehicle (TSRV) ready to perform terminal area research.	Provide flight research capability for support of TAP technology development and demonstration.
Plan: September 1998 Actual: December 1998	Aircraft modifications and research systems installation completed. Flight demonstration revised to December 1998 due to unplanned technical difficulties.
Demonstrate Advanced Vortex Sensing System with transport of vortices and class-wise spacing	Conduct field evaluation of an initial demonstration of AVOSS technologies with transport of vortices and class-wise spacing features. Will demonstrate performance of vortex transport models for use by FAA to potentially reduce approach spacing standards.
Plan: September 1999	
Flight test full CTAS coordinated with FMS Plan: April 2000	Conduct field evaluation of Center-Terminal Radar Approach Control (TRACON) Automation System (CTAS) decision support tools operating in coordination with aircraft Flight Management System.
Complete demonstrations of all TAP-developed technologies and procedures Plan: September 2000	Complete all of the demonstrations for the TAP project. Demonstrate all TAP technologies in a realistic NAS environment achieving a 12 - 15 % increase in single runway throughput and proving the ability to apace aircraft closer than 3,400 feet on parallel runways while meeting all FAA safety criteria.

Advanced Air Transportation Technology:	
Complete definition of expanded operational evaluation for complex airspace and distributed air/ground traffic separation Plan: September 1999	Complete studies and down-select to recommended operational evaluations for both complex airspace and for distributed air/ground traffic separation.
Develop and demonstrate extended terminal area decision support tools for arrival, surface and departure operations Plan September 2000	Conduct field evaluations of individual decision support tools for management of arrival, surface and departure traffic.
Civil Tiltrotor:	
Flight database of low-noise operating procedures Plan: July 1999	Acquire in-flight database for low-noise operating procedures.
Isolated Rotor database for low-noise rotor concept Plan: December 1999	Acquire rotor database for low-noise rotor concepts and for code validation.
Full-span civil tiltrotor wind tunnel testing. Plan: September 1999 Revised: January 2000	Complete full-span, wind-tunnel testing of civil tiltrotor model to demonstrate low noise rotor concepts and acoustic code validation with wake and fuselage effects. Test delayed due to unavailability of wind tunnel due to technical problems

ACCOMPLISHMENTS AND PLANS

In FY 1998, the FAA selected three of the (CTAS) decision support tools developed by the **Advanced Air Transportation Technology** project for implementation as part of Free Flight Phase 1. The Collaborative Arrival Planning (CAP) tool was installed in the American Airlines Systems Operations Center at Fort Worth, TX. The first step in eventually accommodating a greater range of user preferences in sequencing and scheduling of arrival traffic in the Center and TRACON airspace was taken. The initial operational evaluation showed improved estimated time-of-arrival, reduced airline status calls to ATC, and assistance in preventing aircraft diversions. A piloted simulation to examine potential human performance issues of controllers and flight crews in the Free Flight environment was conducted with airline crews and air traffic controllers. This integrated ground/flight deck simulation provided new insights into human factors issues associated with self-separation, including workload, timing, and communication, for range of separation scenarios. In the **Terminal Area Productivity** project, the electronic moving map (EMM) display and HUD symbology study was completed. Sixteen airline crews completed 21 simulated landing-and-taxi-to-the-ramp trials at Chicago-O'Hare in NASA's Advanced Concepts Flight Simulator. Preliminary analysis show that the addition of the T-NASA displays (EMM and HUD) eliminated virtually all crew taxi errors. Taxi speeds were increased by 26% for day IMC crews, and 18% for the night VMC crews. Also all Aircraft Vortex Spacing System (AVOSS) subsystems were proven in initial deployment at Dallas Fort Worth. Early results indicate significant capacity gains possible if and when AVOSS is completed. For example, spacing reductions of up to 1 mile between certain pairs of aircraft may be achievable under frequently occurring weather conditions. The seventh comprehensive piloted simulation of the **Civil Tiltrotor** project completed the development of a comprehensive simulation database on control and display concepts. This latest simulation evaluated a new Flight Path Vector display format and terminal area guidance algorithms. These tests included several scenarios of adverse weather, changing air traffic, and engine failure.

During FY 1999, in the **Advanced Air Transportation Technology** project, the definition of an expanded operational evaluation of advanced air transportation technologies for application to complex airspace and for distributing tasks between flight crews and ground controllers for safe air to air separation will be completed. In the **Terminal Area Productivity** project, a flight test will be conducted to demonstrate the CTAS on the ground and advanced FMS in the flight vehicles utilizing data-link capabilities to facilitate information exchange between CTAS FMS. In the **Civil Tiltrotor** project, wind-tunnel testing of an isolated rotor model will acquire a database for low noise rotor concepts and acoustic code validation and a flight experiment will be conducted to obtain an acoustic/operations database for low-noise flight operating procedures.

During FY 2000, in the **Advanced Air Transportation Technology** project, field evaluations will be conducted to evaluate and demonstrate individual decision support tools for management of arrival, surface and departure traffic. Expect to demonstrate potential for 30% increase in throughput for extended terminal area. The **Terminal Area Productivity** project will be completed in FY2000 with the final demonstration of all developed technologies and procedures. Program expected to demonstrate potential for an increase of 12 to 15% in airport throughput. Specifically, a flight test will be conducted to demonstrate CTAS decision support tools on the ground and an advanced FMS on the aircraft utilizing data-link capabilities to facilitate information exchange between the two systems. In the **Civil Tiltrotor** project, wind -tunnel testing of a full-span tilt-rotor model will demonstrate low-noise rotor concepts and will validate acoustic codes with wake and fuselage effects.

BASIS OF FY 2000 FUNDING REQUIREMENT

AVIATION SAFETY PROGRAM

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Aviation Safety Program	0	0	60,000

PROGRAM GOALS

The world-wide commercial aviation major accident rate has been nearly constant over the past two decades. While the rate is very low (approximately one hull loss per 2 million departures), increasing traffic over the years has resulted in the absolute number of accidents also increasing. The world-wide demand for air travel is expected to increase even further over the coming two decades - more than doubling by 2017. Without an improvement in the accident rate, such a traffic volume would lead to 50 or more major accidents a year — a nearly weekly occurrence. Given the very visible. damaging, and tragic effects of even a single major accident, even approaching this number of accidents would clearly have an unacceptable impact upon the public's confidence in the aviation system, and impede the anticipated growth of the commercial air-travel market. The safety of the general aviation (GA) system is also critically important. The current GA accident rate is many times greater than that of scheduled commercial transport operations. With the GA market is also poised to grow significantly in future years, safety considerations must be removed as a barrier if this growth is also to be realized. Controlled Flight into Terrain (CFIT) and loss of control are the two largest commercial accident types, with weather, approach and landing, and on-board fire as additional significant categories. Human error is cited above all other issues as the prime contributing factor. For General Aviation, weather issues, CFIT, and loss of control also dominate the accident statistics.

In February 1997. to aggressively address these issues, President Clinton announced a national goal to reduce the fatal accident rate for aviation by 80% within ten years. This national aviation safety goal is an ambitious and clear challenge to the aviation community. NASA responded to the President's challenge with an immediate major program planning effort to define the appropriate research to be conducted by the Agency. Four industry- and government-wide workshops were conducted in early 1997 to define research needs. Four hundred persons from over one hundred industry, government, and academic organizations actively participated in setting the research investment strategies. This led to NASA's aviation safety initiative and a redirection of the Aeronautics Research and Technology Base in FY 1998 to immediately begin aviation safety research. The Aviation Safety Program (AvSP) is NASA's next step in responding to the challenge. The goal of AvSP is to develop and demonstrate technologies that contribute to a reduction in aviation accident and fatality rates by a factor of five by the year 2007 compared to the 1994-1996 average.

STRATEGY FOR ACHIEVING GOALS

The NASA AvSP approach for contributing to the national goal is to develop and demonstrate technologies and strategies to improve aviation safety by reducing both aircraft accident and fatality rates. Program planning gives high priority to those strategies that address factors determined to be the largest contributors to accident and fatality rates as well as those that address multiple classes of factors. Research and technology development will address accidents involving hazardous weather, controlled flight into terrain, human-error-caused accidents and incidents, and mechanical or software malfunctions. The safety program will emphasize not only accident rate reduction, but also a decrease in injuries and fatalities when accidents do occur. The program will also develop and integrate information technologies needed to build a safer aviation system--to support pilots and air traffic controllers--as well as provide information to assess situations and trends that might indicate unsafe conditions before they lead to accidents. The focus of each program element is the development of one or more prevention, intervention, or mitigation strategies aimed at one or more causal, contributory, or circumstantial factors associated with aviation accidents.

The AvSP will work as partners with the Federal Aviation Administration (FAA) in implementing the program and will maintain close coordination with the Department of Defense and other government agencies. Additionally, the program will work in concert with the full spectrum of commercial, rotorcraft, and general aviation industry manufacturers, suppliers, and operators in implementing the effort. Langley Research Center (LaRC) is the program's Lead Center and works closely with program personnel at Ames (ARC), Glenn (GRC), and Dryden (DFRC) Research Centers.

The AvSP programmatic and technical approach has been developed in close cooperation with the Federal Aviation Administration as well as the broad aviation community. The Aviation Safety Program Manager is a member of the Commercial Aviation Safety Team and the General Aviation Joint Steering Committee, the government/industry leadership groups developing and managing the overall National safety strategies. NASA aviation safety research and development efforts will therefore complement both FAA and industry activities as a coordinated overall effort.

The technology development and investment strategy for Aviation Safety Program is based upon a data-driven approach. Resources and technology efforts are focused on those accident categories and causes which that data show are most significant. Based upon analysis of National Transportation Safety Board Accident Statistics and other relevant aviation safety data, each technology project activity will have developed measures of projected accident rate impacts by the start of the AvSP in FY 2000. These metrics will be continuously tracked and updated throughout the program.

Success of technology development will be based on the demonstration of sufficient technology maturity to enable partners and customers to adopt and complete the technology application. This maturation process will be assessed as Technology Readiness Levels (TRL). In general, the AvSP will develop technologies to which demonstrates a technology through a system or subsystem model or prototype in a relevant environment.

Associated with each technology development effort will be on-going activities by NASA and the FAA to motivate and assist in the implementation of program outputs into the aviation community. NASA researchers will stay involved to help program "outputs" become "outcomes." This process will mean that NASA will work industry and FAA partners to progress technologies through implementation. This process will be assessed through an Implementation Readiness Level (IRL) scale complementing the TRL scale noted above.

As a partnering strategy aimed at securing participation from organizations motivated to bring advanced safety technologies to implementation, the program will emphasize cost-shared cooperative agreements requiring matching or greater funds from industry partners.

The Technical Program is comprised of six major projects: Aviation System Monitoring and Modeling (ASMM) project provides decision makers in air carriers, air traffic management, and other air services providers with unprecedented in-depth measures of the health, performance, and safety of the National Aviation System (NAS). Capitalizing on revolutionary advances in information technologies and digital communications, ASMM applications will enable definition of operational and safety baselines and trends and identification of developing conditions that could compromise aviation safety. ASMM output will also provide technology and procedure developers with the capability for reliable predictions of the system-wide effects of potential changes introduced into the aviation system. System technologies will first be implemented within specific organizations, but will be readily and subsequently expanded to national and world-wide applications.

The three-fold approach of ASMM is to (1) develop advanced information technology linkages, data structures, and tools to readily access information pertaining to all aspects of the NAS operation, (2) develop tools to identify, analyze and characterize both normal and non-normal operations and uncover previously unrecognized situations that may indicate changes to levels of safety, and (3) provide world-wide capabilities to obtain, access, and share relevant data on aviation operations among the aviation community.

System-Wide Accident Prevention (SWAP) project address aviation safety issues associated with human error and procedural non-compliance, which are broadly applicable throughout the aviation system. As human error is a factor in 60-80% of aviation accidents, generally reducing or mitigating the effect of human error will result in significant reductions in the aviation accident rate. SWAP will pursue research activities in three key areas identified from in-depth assessments as the highest priority applications: (1) Human Error Modeling, (2) Training, and (3) Maintenance Human Factors. Human Error Modeling efforts will target key aviation hazard issues (such as flight deck automation hazards, controlled flight into terrain, and others) to develop, test, and prove general design principles and operational improvements from a human-centered perspective. Training research efforts will target both training effectiveness improvements (training to performance levels over training to pass a test) as well specific training module developments for key safety issues such as flying in icing conditions. Maintenance Human Factors will make key investments in developing applications for procedural improvements and will as technologies for advanced displays and automation.

Single Aircraft Accident Prevention (SAAP) projects develop and support the implementation of safety technologies for in-flight applications. Based upon current accident data, the leading accident categories that SAAP will address are Controlled Flight Into Terrain (CFIT), Loss of Control in Flight, and Runway Incursion (RI) type accidents. Human factors issues and considerations cut across all of these categories and will be an integral part of the technology development process. Both commercial transport and general aviation vehicle classes are included. SAAP will pursue research activities in the following technology areas: (1) Health Management and Flight Critical Design Technologies, and (2) Control Upset Management. Health Management and Flight Critical

Design technology developments will utilize advanced on-board measurement and diagnostic methodologies to monitor key flight systems for both hard failures and previously unrecognized trends leading to failures. Significant safety improvements and maintenance cost savings are expected. Control upset management technologies will target automated and pilot control techniques to prevent aircraft upsets resulting from systems failures or external inputs as well as techniques for recovering from unusual attitude conditions should an unavoidable upset occur.

Weather is a factor in approximately 30 % of aviation accidents. In addition, the majority of CFIT and GA "Loss Control" accidents result from visibility-induced crew errors, where better weather information or better pilot vision would have been a substantial mitigating factor. **Weather Accident Prevention** (WxAP) projects will develop and support the implementation of technologies to reduce the fatal accident rate induced by weather hazards. All aircraft types are to be considered. WxAP will pursue research activities in the following technology areas: (1) Aviation Weather Information Dissemination and Presentation and (2) Turbulence Detection and Mitigation. Aviation Weather Information Dissemination and Presentation technologies will bring implemented cockpit graphical weather display systems to early operational use. Ground-based, satellite, and in-flight weather information products, a digital communications infrastructure, and flight deck displays are to be developed and evaluated in commercial operation. Future growth of weather products and pilot decision aids will follow. Turbulence detection and mitigation technologies are aimed at eliminating the leading cause of in-flight injuries for the airlines. Improved forecasting, predictive sensing, and hazard characterization technologies are to be developed and tested in an integrated systems-based approach to turbulence avoidance.

Nearly all controlled flight into terrain commercial transport accidents and a significant percentage of general aviation accidents result from visibility-induced pilot errors. When terrain, obstacles, or (for low-experienced pilots) the horizon are not visible at night or in poor weather, simple mistakes (which would be readily apparent in clear daylight) can turn into major accidents. A potentially powerful approach to completely eliminate such consequences is to target this visibility-based problem with a vision-based solution. By developing precision navigation applications, high resolution terrain data bases, and graphical cockpit displays, **Synthetic Vision** technology development will provide commercial and general aviation pilots with clear out-the-window views regardless of the actual visibility conditions. In addition to the potentially very large safety improvements, which would result from such a revolutionary system, substantial operational benefits should also result from added all-weather aircraft capabilities. The Synthetic Vision project will focus on technologies and system applications of terrain displays, precision approach and landing guidance and displays, and low visibility surface operations. Close cooperation with the FAA for overall certification issue resolution, and the National Oceanic and Atmospheric Administration (NOAA) and the National Imagery and Mapping Agency (NIMA) for terrain data base development is planned. In addition, engaging airline, avionics, and airframe industry/government partnerships is planned to maintain a focus on actual system implementations.

Accident Mitigation (AM) projects will develop, enable, and promote the implementation of technology to increase the human survival rate in survivable accidents, and to prevent in-flight fires. To reach a goal of reducing fatalities, the number of survivors needs to be increased in accidents that are of the severity level where some, but not all, passengers survive. Fatalities are the result of impact factors, fire/smoke, or some combination of both. The overall approach in AM is to reduce the physical crash dynamics hazards, minimize fire effects in order to allow more time for evacuation, and reliably detect/suppress in-flight fires. AM technologies are targeted at all classes of aircraft.

SCHEDULE AND OUTPUTS

Aviation System Monitoring and Modeling:	
Apply Aircraft Performance Monitoring System (APMS) to Air Traffic Control (ATC)	Demonstrate application of APMS concepts & methodologies to ATC for performance monitoring
Plan: June 2000	
System-Wide Accident Prevention:	
CD-ROM Icing Training Module	Develop CD-ROM icing training module for GA and commuter pilots.
Plan: September 2000	
Simulation Database for Adverse Conditions and Loss of Control	Complete development of a preliminary simulation database, mathematical models and 6 degree-of-freedom vehicle simulations to characterize adverse conditions, failures, and loss of control
Plan: September 2000	
Weather Accident Prevention	
Initial Aviation Weather Information Network (AWIN) Concept Flight Evaluation	Flight Evaluation of initial national capability for digital data link and graphical display of weather information.
Plan: September 2000	
Synthetic Vision (SV):	
Flight Demonstration of Runway Incursion Prevention Technologies	Concept demonstration of integration of air traffic control runway incursion information onto aircraft flight deck displays.
Plan: September 2000	

Accomplishments and Plans

FY 2000: $60.0 million

In FY 2000, the Weather Accident Prevention project will complete flight evaluation of an initial national capability for digital data link and graphical display weather information in an aircraft cockpit. This will be an assessment of a cockpit "weather channel" concept for national and worldwide commercial airline and general aviation benefit. Selections of concepts for continued development will be conducted for clear air turbulence detection systems. The System-Wide Accident Prevention project will develop and demonstrate an icing training module on CD-ROM for general aviation and commuter pilots. This will enable the broad dissemination of critical weather safety information to the national aviation community. Software application field tests will begin for maintenance human factors risk and task analyses. The Single Aircraft Accident Prevention project will develop an initial simulation database, mathematical models, and six degree-of-freedom vehicle simulations to characterize adverse conditions, system failures, and loss of control mitigation techniques. Synthetic Vision flight demonstration tests of FAA and NASA runway incursion technologies integrated onto an aircraft flight deck will be conducted at a major U.S. airport. These tests will provide technical and operational system performance assessments of the integration of airport surface databases and runway incursion warning systems into current technology cockpits. The Aviation System Monitoring and Modeling project will demonstrate the application of Aircraft Performance Measurement System concepts and methodologies to Air Traffic Control systems for performance monitoring. This work will take successful aircraft-based monitoring technologies and apply them to the broader context of the national airspace system risk identification and performance improvements. Airline evaluations and operational use of aircraft performance measuring software and analysis tools will be conducted. In the Accident Mitigation projects area, on-board inert gas and oxygen generation system concepts for fire prevention and emergency use will be defined and structural crashworthiness design analysis prediction codes development selections will be conducted.

BASIS OF FY 2000 FUNDING REQUIREMENT

ULTRA EFFICIENT ENGINE TECHNOLOGY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Ultra-efficient engine technology			50,000

PROGRAM GOALS

NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. Currently, a high priority national challenge is to ensure U.S. leadership in aviation in the face of growing air traffic volume, new safety requirements, and increasingly stringent noise and emissions standards. NASA's role in aeronautics is also to support the Department of Defense (DoD) in maintaining superior defense capability. Propulsion has led the way for new generations of aircraft with breakthroughs in performance, reliability, and environmental compatibility. A prime example of NASA's contribution to technological advances in propulsion is the high bypass turbofan. This engine enabled the economic success of wide-body transport aircraft and achievement of new levels of fuel efficiency and dramatically reduced noise as compared to the earlier generation of jet aircraft. The attainment of Aero-Space Technology Enterprise goals requires comprehensive propulsion technology research and development spanning a broad range of aircraft applications from subsonic through hypersonic. The timing is right to invest in breakthrough technologies for a new breed of radically improved propulsion systems to power a new generation of aircraft required in the increasingly constrained airspace system.

NASA has a successful history of leading the development of aggressive high payoff technology in high-risk areas, ensuring a proactive approach is taken to developing technology that will both be required for meeting anticipated future requirements, and for providing the technical basis to guide policy by determining feasible technical limits. The Ultra Efficient Engine Technology Program addresses the most critical propulsion issues facing the Nation in the new millennium: performance and efficiency. In order to sustain the desirable forecasted growth of this important industry, these issues must be addressed without dampening this growth and therefore must improve performance and efficiency without incurring environmental penalties. Additionally, it is important to sustain the high reliability and safe operation without impacting the economics of operations. These propulsion technologies will also be of significant benefit to military engines where performance improvement is the principal goal driving DoD propulsion development for future military aircraft.

STRATEGY FOR ACHIEVING GOALS

The Ultra Efficient Engine Technology Program is planned and designed to develop high-payoff, high-risk technologies to enable the next breakthroughs in propulsion systems to spawn a new generation of high performance, operationally efficient and economical, reliable and environmentally compatible U.S. aircraft. The breakthrough technologies are focused on propulsion component and high temperature engine materials development and demonstrations enabling future commercial and military propulsion systems which are greatly simplified, achieve higher performance, and have potential for much reduced environmental impact with a broad range of aircraft application. Four investment areas form the basis for the technical approach: materials & structures, to address the barrier technologies and expand the knowledge databases associated with high temperature; combustion, to develop the technology necessary to address efficient high temperature, high pressure. High performance systems; turbomachinery, to develop highly coupled/loaded engine component technologies incorporating breakthrough features with potential for integrated propulsion demonstrations; and integration & assessments, to understand the complexity of interplay among technology benefit, tradeoff and impact.

NASA's investments will develop the underlying understandings and design information to mitigate both the risk and cost of applying the technology-based solutions. The success of this program is dependent on partnerships to enable transfer of the resulting technology. As a result, a key element of this program is to develop high-payoff technologies, in cooperation with DoD, the Federal Aviation Administration (FAA), the U.S. aeronautics industry and academia, to benefit the public.

SCHEDULE AND OUTPUTS

Combustion: Combustion research facility upgrade completed Plan: September 2000	Make operational the second leg of the Advanced Subsonic Combustion Rig, a unique world class facility, which is required for testing of combustor configurations (flame tube and sector) required for future ultra high pressure ratio engine cycles.
Combustion: Select 70% emissions reduction concept for full combustor evaluation Plan: September 2000	Demonstrate in a laboratory combustion experiment (flametube) an advanced turbine-engine combustor concept that will achieve up to a 70% reduction of oxides of nitrogen (NOx) emissions based on 1996 ICAO standard.
Materials & Structures: Complete high temperature engine material down-select Plan: September 2000	Complete selection of those materials systems that will be developed for complex geometry's such as cooled turbine vanes with thermal barrier coating and capable of sustained 3100°F turbine rotor inlet temperatures
Turbomachinery: Validation of aero-performance prediction code Plan: September 2000	Complete single stage cascade tests of turbine configurations which incorporate flow control to improve aerodynamic performance and use flow physics data set acquired to validate NASA's average passage (APNASA) computer code

ACCOMPLISHMENTS AND PLANS

This is a new program beginning in FY 2000

In **Combustion**, the world class high pressure ratio combustion research facility upgrade will be completed to allow parallel operation of basic combustion research for combustion diagnostics and physics based model calibration and for sector testing to validate advanced high performance combustor designs. The facility leg already in place will be conducting final flame tube and initial sector experiments on high pressure combustor concepts in the process of identifying solutions and combustor designs to achieve dramatic reductions in NO_x production.

In **Materials & Structures**, the selection of those materials systems that will be developed to the subcomponent, complex part scale in this program will be completed. The suite of materials from which this selection will be made is the suite is focused only on those critical to enable the high performance 21^{st} Century propulsion systems. An initial high priority activity will be to move a preliminary high temperature material and coating from the laboratory to realistic scale parts for evaluation and analysis, including the thermal barrier coating. This will enable the early demonstration of a significant increase in engine temperature with commercial life. One critical material system, ceramic matrix composites, is essential to both future commercial and military engines. This program is the only national effort in CMCs and is a key technology where DoD is reliant on NASA. Work on high temperature, lightweight organic matrix composites will also be initiated

In **Turbomachinery**, a set of single stage cascade tests of turbine configurations will be completed which incorporate flow control enabling unprecedented levels of aerodynamic performance and use flow physics data set acquired to validate APNASA code. Initial research on single stage aspirated compression components will be accomplished with the target for proof of concept test for the following year.

In **Integration & Assessment**, studies will be performed to quantify key program metrics and minimum success criteria and to guide program investments, and to define viable tradeoffs of technologies with interdependent system benefits. Of particular interest is defining the environmental benefits, tradeoffs, and impacts.

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY **ADVANCED SPACE TRANSPORTATION TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET
		(Thousands of Dollars)	
X-33 Advanced Technology Demonstrator	318,300	277,300	111,600
[Stennis Space Center Test Stand Modification CoF]	[3,700]	[--]	[--]
X-34 Technology Demonstration Program	26,700	35,500	25,500
Future-X Demonstration Program	--	36,000	31,300
Future Space Launch Studies	10,000	30,000	30,000
Advanced Space Transportation Program (ASTP)	62,100	50,800	55,600
Total	417,100	429,600	254,000

Distribution of Program Amount by Installation			
Johnson Space Center	4,757	1,745	934
Kennedy Space Center	668	1,036	900
Marshall Space Flight Center	325,935	321,248	207,106
Stennis Space Center	16,990	30,340	1,269
Ames Research Center	12,258	10,156	7,605
Dryden Flight Research Center	6,230	7,413	3,093
Langley Research Center	13,958	22,650	13,546
Glenn Research Center	11,500	11,636	8,567
Goddard Space Flight Center	1,080	40	30
Jet Propulsion Laboratory	9,046	4,166	1,646
Headquarters	14,678	19,170	9,304
Total	417,100	429,600	254,000

ADVANCED SPACE TRANSPORTATION TECHNOLOGY

PROGRAM GOALS

The goal of Advanced Space Transportation Technology is to develop and demonstrate new technologies aimed at revitalizing access to space and in-space transportation. These new technologies are targeted to dramatically reduce launch costs, increase the safety and reliability of current and next generation launch vehicles, and significantly improve the technical performance of in-space transportation systems to reduce the cost of NASA's science and exploration programs and enable new, more challenging, missions.

STRATEGY FOR ACHIEVING GOALS

NASA's primary space transportation technology role is to develop and demonstrate pre-competitive, next-generation technology that will enable the commercial development of truly affordable and reliable space transportation systems – the third pillar for success of the Aero-Space Technology Enterprise. Success in this challenging endeavor would enable the U.S. to recapture worldwide commercial space markets, while dramatically improving transportation capabilities for civil missions and sustaining military missions. Consistent with the National Space Transportation Policy, NASA, as a member of the national team, will develop technology for the next generation of reusable space transportation systems, with a target of reducing launch and space transfer vehicle development and operations costs dramatically in the next decade. NASA will also support DoD in developing and demonstrating technologies which support Evolved Expendable Launch Vehicle and Military Spaceplane objectives, as well as participate in the government/industry Integrated High Payoff Rocket Propulsion Technology (IHPRPT) initiative.

Advanced Space Transportation Technology has three primary components: Reusable Launch Vehicle (RLV), the Advanced Space Transportation Program (ASTP) and Future Space Launch Studies. Incorporating innovative partnerships with industry, other agencies and academia, the RLV and ASTP programs encompass the flight and ground demonstration of advanced and enabling technologies required to revolutionize space access. The combined program ranges from the exploratory research of high pay-off emerging technologies, taking advantage of aeronautics investments as appropriate, to the flight demonstration of advanced technologies by X-Vehicles. Requirements for these technology investments will be defined in cooperation with other NASA enterprises, the Department of Defense (DoD), and commercial industry.

The Future Space Launch Studies are industry-led studies to develop options and roadmaps in support of future decisions on space transportation architecture elements, which will significantly reduce NASA's launch costs. In the near term, X-vehicle ground and flight demonstrations, RLV business planning, and the Future Space Launch Studies will provide the basis for an end-of-the-decade decision, as called for in the 1994 National Space Transportation Policy, on an appropriate strategy for significantly reducing NASA's launch costs. The studies will also inform decisions to be made in FY 2000 on the pursuit of a Crew Return Vehicle (CRV) for the International Space Station. In preparation for these decisions, the Administration has included over $1 billion in the Future Space Launch Development budget line between FY 2001 and FY 2004 to support activities to be undertaken in accordance with the recommendations resulting from the Future Space Launch Studies.

Reusable Launch Vehicle (RLV)

The RLV program includes systems engineering and concept analysis, ground-based technology development, and a series of flight demonstrators: the X-33 Advanced Technology Demonstrator, the X-34 Technology Testbed demonstrator, and Future-X Pathfinders. In FY 1999 and FY 2000, the RLV program will consist of the X-33, X-34 and recently selected Future-X Pathfinder projects. Each part of these programs contribute to validating key component technologies, proving that they can be integrated into functional vehicles and demonstrating low-cost operations in relevant flight environments. These programs build on the technologies being developed in the Advanced Space Transportation Program and are limited to technologies that require flight demonstration

X-33 Program

The X-33 objective is to demonstrate technologies and operations concepts with the goal of reducing space transportation costs to one tenth of their current level. The X-33 program includes two major decision points. The first, whether to proceed with Phase II, was completed in July 1996 and was made based on specific programmatic, business planning, and technical criteria which had previously been agreed upon by NASA, the Office of Management and Budget and the Office of Science and Technology Policy. NASA selected the Lockheed Martin Skunkworks to lead an industry team to develop and fly the X-33. First flight of the vehicle is now planned for July 2000. The second decision will be made after X-33 ground and flight tests, when government and industry will consider whether to pursue in Phase III the private financing of the development and operations of a full-scale operational RLV. At that point, if the industry partners and investment community are not satisfied that the technological risk is low enough to proceed, NASA could pursue other options, including the possibility of continued RLV technology work to accomplish further risk reduction. For example, the X-33 may require technology enhancements, or a follow-on vehicle to the X-33 may be needed to prove ultimate feasibility.

NASA is utilizing an innovative management strategy for the X-33 program, based on industry-led cooperative agreements. As a result of industry's leadership of the program, the participants are not playing traditional roles, with government overseeing and directing the work of the industry contractors. Instead, government participants are acting as partners and subcontractors, performing tasks for industry because industry believes that these government team members offer the most effective means to accomplish the program objectives. The government participants report costs and manpower to the industry team leader as would any other subcontractor. The industry-led cooperative arrangement allows a much leaner management structure, lower program overhead costs, and increased management efficiency.

The X-33 is an integrated technology effort to flight-demonstrate key Single Stage To Orbit (SSTO) technologies, and deliver advancements in: 1) ground and flight operations techniques that will substantially reduce operations costs for an RLV; 2) lighter, reusable cryogenic tanks; 3) lightweight, low-cost composite structures; 4) advanced Thermal Protection Systems to reduce maintenance; 5) propulsion and vehicle integration; and 6) application of New Millennium microelectronics for vastly improved reliability and vehicle health management. X-33 will combine its results with the successes of the DC-XA, X-34 and complementary ground technology advances to reduce the technical risk of full-scale development of an operational RLV. The X-33 test vehicle will fly 13-15 times the speed of sound and will test the boundaries of current technology. Together, the DC-XA, X-34, and X-33 will provide a number of flight tests of key technology demonstrations prior to the decision to privately finance the development and operations of the next generation RLV system.

The X-33 Program is also funding refurbishment of the test complex infrastructure at the Stennis Space Center (SSC). The B-2 test stand required $3.7 million in FY1998 appropriations, and the A-1 test stand required $5.5 million of FY 1999 appropriations. The test complex infrastructure support requirements relative to X-33 for FY 2000 and beyond (if any) are to be defined in appropriate Task Agreements with industry and incorporated into the X-33 cooperative agreement.

It is envisioned that private industry will have a primary role in the funding, development, and operation of a next-generation launch system. Therefore, business venture plans are as critical to the RLV program as any technical advancements made on the experimental vehicles. Programmatic and business plans for an operational commercial RLV, expressed in innovative industry-developed and -led business plans, will receive equal consideration with technology demonstrations in future decisions on developing an operational launch vehicle. These plans will address policy and legislative issues as well as private financing options, and will inform the Future Space Launch Studies.

X-34

The X-34 program will demonstrate technologies necessary for a reusable vehicle, but will not be a commercially viable vehicle itself. It will be a rocket-powered, Mach-8-capable flight demonstrator test bed to close the performance gap between the subsonic DC-XA and the Mach 13+ X-33. The X-34 objective is to enhance U.S. commercial space launch competitiveness through the development and demonstration of key technologies applicable to future, low-cost reusable launch vehicles. The X-34, now planned to fly for the first time in late 1999, will demonstrate flexible integration capability, high flight rate (25 flights per year), autonomous flight operations, safe abort capability, and a recurring flight cost of $500,000 or less. The X-34 program is procuring two flight vehicles, in keeping with the usual practice in X-vehicle programs, to ensure that the program meets its objectives without constraining the aggressiveness of the demonstration effort.

The 50-month, fixed-price X-34 contract is being conducted by Orbital Sciences Corp. of Dulles, Virginia. NASA's Ames, Langley, Dryden, Marshall, Kennedy and White Sands complexes and Holloman Air Force Base are all involved in the program. The government's work responsibilities include primary propulsion development, thermal protection system integration, wind tunnel support, and testing and flight operations.

After completion of the first flight series (the basic contract includes two flights), the X-34 program is planning a second phase for additional flight testing of up to 25 flights in one year. These flights will demonstrate key embedded technologies and systems operations, as well as additional technology experiments and test articles from the RLV and Advanced Space Transportation programs. X-34 modifications and experiments will benefit from being comparatively small, thereby lowering the expense and risk of demonstrating the technologies, and making their integration into the vehicle less costly. The low-cost X-34 demonstrator will increase the scope and aggressiveness of flight demonstrations, thus increasing the return to the RLV program.

Future-X Pathfinder

As part of NASA's core mission to advance the state-of-the-art in aeronautics and space transportation, the Agency will continue to develop and demonstrate advanced technologies through the use of experimental flight vehicles. The primary objective of this "Future X" program is to flight demonstrate technologies which can dramatically reduce the cost and increase the reliability of reusable space launch and orbital transportation systems. Future-X Pathfinder demonstrations build on ASTP technologies by carrying out small-scale flight demonstrations every 12-24 months. Pathfinder projects demonstrate cutting-edge technologies with high payoff potential and cost between $1M and $100M.

NASA recently selected proposals and began funding new Pathfinder-class demonstrations in FY 1999. One new Pathfinder demonstrator and seven flight experiments were selected for initiation in FY 1999. Those projects are under negotiation, and project details will be provided at a later time. These selections will enable NASA to continue pushing the state of the art in launch vehicles by demonstrating technologies that are one generation beyond those contained in the X-33 and X-34 demonstrators. The selected Pathfinders include:

- a modular orbital flight testbed called the Advanced Technology Vehicle (ATV), an experimental vehicle to be flown in both orbital and reentry environments.
- a Hall-effect Solar Electric Thruster system flight demonstration of new onboard in-space propulsion technologies;
- an experiment to demonstrate an onboard intelligent planning system for autonomous abort;
- an experiment to demonstrate technologies that will significantly reduce the access-to-space costs of small payloads;
- an experiment to demonstrate advanced technologies of an integrated vehicle health management system;
- an experiment to demonstrate ultra-high temperature ceramics for reusable, sharp hypersonic leading edges;
- an experiment to demonstrate propulsion technologies that will reduce the weight and size of advanced cryogenic upper stages;
- an experiment to demonstrate advanced in-space propulsion technologies using an electrodynamic tether.

Advanced Space Transportation Program (ASTP)

ASTP is the technology base program for space transportation. Future revolutionary advances in space transportation technology will be developed in this program to reduce costs and increase reliability and performance across the entire mission spectrum. Advanced technologies will be developed and ground-tested to bring them to readiness levels where they can either be adopted by industry, or if necessary, flight-proven in the RLV technology program. The ASTP will focus on technological advances with the potential to reduce launch costs beyond X-33 and Pathfinder demonstrators -- aiming at a cost-to-orbit measured in hundreds, not thousands, of dollars per pound, in accordance with Aero-Space Technology Enterprise Goal 9. In addition, ASTP will make key technology investments for in-space transportation systems to reduce costs, system mass and trip time for future in-space missions in accordance with OAT Goal 10.

The ASTP has been restructured to form focused, core and research investment areas.

- Focused projects have a strong technology pull based on near-term operational system development needs. The current focused projects support the next-generation reusable launch vehicle (RLV), small payload launch, and in-space transportation systems. Core projects push the state of the art in propulsion and airframe systems towards the long-term program goals.
- Core technology priorities are derived from the contribution of each technology to overall transportation system objectives.
- The space transportation research concentrates on very advanced, breakthrough concepts for revolutionizing space travel.

The ASTP program is utilizing competitive technology selection and procurement processes wherever feasible in order to maximize the involvement of the myriad traditional sources of space transportation technology throughout the country, as well as to bring in potential new sources. An inter-center process has been established to prioritize ASTP technology investments based on their system payoff in terms of improvements in mission capability, cost, reliability, operability, responsiveness, and safety. The goals, objectives, and progress of the ASTP will be evaluated on a yearly basis by a panel of nationally recognized experts to ensure program content is consistent with government and industry priorities, and that the program is yielding the maximum possible return on the taxpayers' investment.

Focused Projects

The **RLV Focused** project will pursue investments in airframe systems and propulsion technologies consistent with goals of the X-33 and Pathfinder programs: to reduce the cost of access to space to $1000/lb in ten years by enabling the full-scale development of an operational RLV shortly after the turn of the century. Funding supports RLV Focused tasks that are complementary to, but do not duplicate, the work funded by X-33. Technology tasks are selected competitively, and are not limited to support of the VentureStar concept, but are applicable to any viable next-generation RLV concept. Technology development has been initiated for durable thermal protection systems, lightweight conformal structures, increased component life capability, low-cost manufacturing, lightweight airframe and propulsion components and advanced power systems.

The **Small-Payload Focused (Bantam)** project has been restructured to develop advanced reusable technologies applicable to systems capable of launching small science and technology payloads. The new goal of the project is to mature and demonstrate unique technologies that will enable the development of a reusable launch system to launch 200- to-300-pound payloads for $1.0M to $1.5 million per flight in the 2004-2005 time frame. A large number of the technologies required to meet this goal also have application to other payload classes and are funded in the Core Airframe and Core Propulsion budget lines. Concepts under study to achieve this goal include multistage rockets, airbreathing combined-cycle vehicles, beamed-energy laser-powered vehicles, and a variety of innovative launch-assisted concepts. Funding supports a phased approach where (1) critical enabling technologies are matured to support concept selection, (2) core reusable technologies that have application to multiple small-payload launch and larger **RLV** concepts are accelerated, and **(3)** the most promising technologies are matured toward flight demonstration within the Future-X Pathfinder program. The project is expected to culminate with a potential Future-X flight demonstration of the most promising vehicle concept in the 2002-2004 time frame.

The **Hybrid Propulsion Focused** project is being conducted under a Cooperative Agreement between NASA, DoD and **U.S.** industry, with the objective of demonstrating hybrid (solid fuel, liquid oxidizer) propulsion technology to enable U.S. industry to commercialize hybrid boosters for space launch operations. Hybrid motors offer potential for safer, lower cost, and environmentally friendlier boosters for **U.S.** launch providers. This resource-shared (experts, facilities and dollars) and jointly-managed program will demonstrate full-size, flight-like boosters on a schedule suitable for application on operational launch systems early in the **2**1st century. The program will accomplish ground test firings of both upper-stage–scale, 10,000-pound-thrust motors and booster-scale 250,000-pound-thrust motors, and is designed to allow rapid development of flight hardware with minimum risk.

The **NSTAR Focused** project supports the design and ground testing of the NASA Solar electric propulsion Technology Application Readiness (NSTAR) ion engine launched on the New Millennium DS-1 spacecraft in October 1998. NSTAR has validated ion propulsion for future robotic planetary missions, as a step toward meeting OAT Coal 10.

The **In-Space Focused** project will pursue technology investments to reduce costs, spacecraft system mass and trip time for future space missions in accordance with Aero-Space Technology Enterprise Goal 10. The project will support technology work in the areas of:: advanced solar-electric and solar-thermal propulsion systems for Earth orbit and planetary transfer: atmosphere-assisted entry for planetary missions and Earth-orbit return: cryogenic fluid management for orbit transfer and exploration missions: and non-conventional transportation systems, such as electrodynamic tethers.

Core Technology

The **Core Propulsion** technology project is pursuing the maturation of advanced, highly reusable technologies, significantly beyond the current state of the art **(X-33** for reusable launch vehicles and NSTAR for in-space transportation systems). The technologies currently being pursued focus on air-breathing rocket-based combined cycles (RBCC). Future technology investments will focus on advanced materials to reduce weight and improve engine life, advanced nozzles to improve performance, and turbomachinery technologies to improve reliability and engine life. The aim is to mature propulsion technologies through ground testing and analyses to the point where they can be considered for a Future X-vehicle flight evaluation. Three RBCC concepts were selected in FY 1996 for preliminary proof-of-concept ground demonstration. These demonstrations will lead to a decision in FY 1999 - 2000 on whether or not to proceed with further development of a flight demonstration project. Propulsion technologies will be addressed in partnership with NASA Aeronautics Centers, DoD and industry to assure maximum synergy between aeronautics research and the systems design and application to space launch.

The **Core Airframe** project is pursuing the maturation **of** advanced, highly reusable airframe and structures technologies significantly beyond the current state of the art for reusable launch vehicles (represented by the ***X-33).*** Airframe systems technologies include structures and materials, cryogenic tanks, thermal protection systems (TPS), avionics/operations, and system analysis, design and integration. Technology investments are just beginning in: advanced composites and refractory composite hot structures development; technologies for both structure and cryotank joints; ultra-high-temperature ceramic thermal protection materials; instrumentation for vehicle health monitoring; and highly reliable avionics systems. The aim is to mature these technologies through ground testing and analyses to the point where they can be considered for a Future X-vehicle flight evaluation. Airframe systems technologies will be addressed in partnership with NASA Aeronautics Centers, DoD and industry to assure maximum synergy between aeronautics research and the systems design and application to space launch.

Space Transportation Research

The **Space Transportation Research** provides the basic research function of the ASTP program. The activity focuses on advanced concepts for enabling breakthroughs in space transportation, maturing these revolutionary ideas via small, critical technology experiments and breadboard validations. This effort relies on partnerships with industry, universities, other agencies and NASA centers to identify longer term technologies with tremendous promise for performance improvement and cost reduction. Areas of interest include advanced concepts for launch augmentation, pulse detonation engines, high-energy propellants, and high-energy concepts and materials which hold promise for enabling exciting new missions that are beyond the realm of present technological capability. The research project is guided by a peer review process involving National experts in the applicable technical fields.

SCHEDULE & OUTPUTS

Reusable Launch Vehicle (RLV)

X-33 Critical Design Review.

Plan: July 1997
Actual: October 1997

The second key review milestone, which closed the vehicle design for production, validated readiness of the vehicle technologies, and defined schedule to first flight. Delayed to solve issues of weight growth and flight stability/controllability.

X-33 EIS Record of Decision

Plan: October 1997
Actual: November 1997

EIS Record of Decision allowed launch site construction to begin. Mitigated several flight safety and environmental issues.

X-33 LO_2 Tank Delivery

Plan: December 1997
Actual: February 1998

Completes design, manufacture, test and delivery. Delay had no impact.

X-33 LH_2 Tank Delivery Plan: June 1998 Revised: March 1999		Completes design, manufacture, test and delivery to MSFC. Delayed because of tank redesign activities and issues with main joint fabrication/testing. LH_2 tank delay is a major factor in X-33 first flight slip from July 1999 to July 2000.
First X-33 Aerospike Engine Test (Powerpack) Plan: March 1998 Actual: September 1998		First complete J2-Aerospike test. Supports first flight-unit engine scheduled for delivery. Late delivery of the engine was due to manufacturing difficulties with the expansion ramps and turbomachinery. Engine delay is a major factor in X-33 first flight slip from July 1999 to July 2000.
X-33 Thermal Protection System Delivery Plan: August 1998 Revised: December 1999		Delivery of complete Thermal Protection System for X-33 flight demonstrator. Delayed due to delay in delivery of LH_2 tank.
X-33 Vehicle to Roll out Plan: May 1999 Revised: January 2000		X-33 flight demonstrator vehicle rollout enabling final checkout. Delayed due to LH_2 tank and aerospike engine delays..
X-33 First Flight Plan: July 1999 Revised: July 2000		The flight test program, based at Edwards Air Force Base, will fly at speeds greater than Mach 13. Delayed due to LH_2 tank and engine delays and reassessment of schedule between roll-out and first flight.
X-34 Engine Delivery Plan: December 1998 Revised: June 1999		Completes design, manufacture, test and delivery. Engine was delayed due to technical problems but is not on the critical path to first flight.
X-34 First Flight Plan: March 1999 Revised: September 1999		The flight test program will expand in increments to assure success. Delayed due to failures in the ground test RP-1 composite tank that delayed start of fabrication of the first flight tank and due to a processing accident in the manufacture resulting in scrapping of the flight wing lower surface. Both problems have been corrected.
X-34 First Powered Flight Plan: August 1999 Revised: December 1999		The flight program will expand the flight profile with initial, unpowered flights to be followed by powered flights that will reach Mach 8. Delayed due to delays in vehicle fabrication, specifically the composite tank and flight wing.

Advanced Space Transportation Program (ASTP)

Begin Bantam Cycle I contracts Plan: July 1997 Actual: December 1997	Four contractors began detailed system studies of low-cost vehicle concepts and enabling technologies. Delayed due to protest by a losing proposer. None of the resulting concepts met the program cost-per-flight goals, leading to restructuring of the program
NSTAR delivery for DS-1 launch Plan: January 1998 Actual: March 1998	Hardware delivered for integration onto spacecraft. Launch of DS-1 occurred on October 24th, three months late, due primarily to spacecraft technical and testing problems. NSTAR ion propulsion system is providing primary propulsion for the mission, and has met minimum mission success/technology validation criteria.
Ground Test First Hybrid 250K Pressure-Fed Motor. Plan: March 1998 Revised: March 1999	Test program was transferred to the Stennis Space Center. Two test motors are ready and awaiting test facility activation. Delayed due to slip in component deliveries
RBCC component-level test completion (Mach 0-4). Plan: May 1998 Revised: September 1998	Ground test of critical low-speed air-breathing, rocket-based combined cycle (RBCC) engine technologies such as inlet design and low-speed air augmentation. Injector, inlet and ignition system test complete. Thruster and low-speed air augmentation test delayed due to test anomalies and scheduling difficulties.
Begin mission profile testing of NSTAR engine Plan: March 1998 Actual: October 1998	Test back-up flight hardware, gather and analyze flight data, and resolve unforeseen flight anomalies. An anomaly in initial NSTAR operation was resolved, in part, through ground test/verification of the failure mode.
Complete RBCC engine testing Plan: August 1998 Revised: September 1999	Integrated engine testing essential to predict propulsion system performance. Facility problems, scheduling difficulties and upgrades to the engine to improve performance based on recently acquired test results have resulted in a revised date.
Complete 500-hour test of 10 kW Hall electric thruster Plan: June 1999 Actual:	First demonstration/validation of high-power electric thruster
Conduct CDR on ProSEDS Plan: August 1999	Propulsive Small Expendable Deployer System (ProSEDS) tether flight experiment scheduled for Critical Design Review.

Initiate Breakthrough Propulsion Physics Experiments. Plan: April 1999	Award Breakthrough Physics experiments under NASA Research Announcement.
Complete design of flight-weight RBCC engine Plan: March 1999 Revised: September 2000	Integrated performance and weight model of operational RBCC vehicle. Could lead to flight-weight engine development if justified by system payoff. Budget reductions due to Agency priorities have delayed this activity.
Ground Test First Hybrid 250K Pump-Fed Motor Plan: March 2000	Modifications of the SSC E1 test stand for pump-fed hybrid motor tests are now being designed. The two pressure-fed test motors will be refurbished to support these tests.
Complete RLV focused technologies tasks Plan: September 2000	Both airframe and propulsion RLV Focused technology activity results available
NSTAR Engine ground demonstration Plan: January 2000	Complete ground demonstration of 100 % design life on the NSTAR ion engine
Complete Small Payload focused technologies and select concepts Plan: September 2000	Concepts will be selected for flight demonstration of a reusable first stage based on FY 1999 and FY 2000 technology development.

ACCOMPLISHMENTS AND PLANS

Reusable Launch Vehicle

X-33

The X-33 program met several critical milestones in FY 1998, including: completion of the vehicle Critical Design Review; initiation of X-33 flight test vehicle assembly; integration of the liquid oxygen tank into the X-33 final assembly fixture; initiation of the two composite liquid hydrogen tank assemblies; and initiation of the powerpack testing at the Stennis Space Center. Initial qualification testing on the thermal protection systems was completed and verified performance of the design. The fourth-unit build of the avionics and software systems was delivered and integration testing initiated, including antenna testing. In FY 1999, the software build and test will continue and all Global Positioning Satellite interface testing will be completed. Assembly and testing of the X-33 will continue in FY 1999, with completion of final integration scheduled in early FY 2000.

The second cycle of design and business planning for the operational Reusable Launch Vehicle, VentureStar, is well underway. A systems design review for VentureStar is to be held in FY 1999 that will provide the basis for Preliminary Design of the VentureStar flight vehicle. Market analyses and RLV capitalization planning for VentureStar was completed in FY 1999, indicating substantial capture of international payload markets and several potential financing options to permit capitalizing commercial development and operations for VentureStar.

In FY 2000, the final assembly of the X-33 will be completed, systems testing and flight testing will be conducted. The information gathered from the X-33 testing and the ground technology program will enable an industry decision on whether to proceed with the development of the VentureStar.

As indicated above, the X-33 program has encountered technical problems, which have resulted in a slip to the schedule of approximately one year since the FY 1999 budget to Congress. However, the government's funding responsibilities under the cooperative agreement are fixed, thus no additional funding will be required, despite the technical issues and delays.

<u>X-34</u>

The X-34 project completed several critical milestones in FY 1998, including:

1. Negotiated and defined the X-34 Characterization and Validation contract modification, which provided: a second flight vehicle for the program, early validation of critical X-34 systems, an unpowered flight prior to powered flight operations, and a gradual expansion of the flight test envelope.
2. Completed build-up of the first (A-1) fuselage, and completed vehicle static load testing.
3. Completed static load testing of the first flight wing, and delivered the wing for vehicle integration.
4. Completed development of the X-34 Main Propulsion System by an in-house MSFC team.
5. Completed the detailed design review of the vehicle Thermal Protection System.
6. Completed testing of the LOX qualification tank.
7. Completed low-speed, in-flight testing of the vehicle avionics at Holloman Air Force Base.
8. Procured through JSC and delivered the first flight set of GFE Main Landing Gear, and procured the second flight set of GFE Main Landing Gear.
9. Supported and participated in an Office of Safety and Mission Assurance-led review of the X-34 program. The review found the X-34 S&MA programs and processes to be satisfactory and appropriate.
10. Began build-up of the second (A-2) fuselage, with upper and lower panels completed, and the forward LOX tank integrated
11. Selected a set of seven TA-2 experiments that will fly on the X-34 vehicle to evaluate new Reusable Launch Vehicle technologies.
12. Began environmental assessment activities for East Coast flight operations by conducting initial program briefings to abort site leaders and key personnel.

13. Established a strong program emphasis on schedule with the prime contractor, despite the fact they do not have a strong schedule incentive due the fixed-price nature of the contract.
14. Established new policies placing responsibility for resolving issues between the prime contractor and government Task Agreement managers with the prime contractor. This has resulted in the prime contractor stepping up to their managerial responsibilities with their government "subcontractors."
15. Exercised the Optional Flight Test Program to conduct a total of 27 flight tests of the X-34 vehicle at White Sands Missile Range and the Kennedy Space Center/Eastern Range.

In FY 1999, the A-1 vehicle will undergo ground vibration testing and captive-carry FAA certification flights at DFRC and Edwards AFB, CA. The A-2 vehicle will be delivered to Holloman AFB for final preparations for, and execution of, the first flight of the X-34 vehicle, an unpowered flight with a landing at the White Sands Space Harbor. In FY 2000, the A-2 vehicle will be installed on the horizontal test stand at Holloman AFB for a full-up, integrated hot fire of the main propulsion system and Fastrac engine. After a successful static test, the vehicle will be prepped and is scheduled to execute its first powered flight over the White Sands Missile Range in December. FY 2000 will mark the beginning of the X-34 extended flight test program. The purpose of this extended test program is three fold: 1) Expand the performance envelope of the vehicle to Mach 8; 2) Demonstrate low cost, high-rate operability; and 3) fly a number of hosted experiments. The project will move from White Sands Missile Range to the Eastern Range to accomplish the remainder of the flights. During this time frame, the flight experiments will be integrated and flown. The second flight vehicle will also be delivered during this year.

As indicated above, the X-34 schedule has slipped approximately six months since the FY 1999 budget to Congress. However, the X-34 contract is fixed-price; therefore, no additional government funding is required.

Future-X Pathfinders:

In FY 1999, the RLV Program initiated the next generation of technology flight demonstration through the selection, announced in December 1998, of a new Advanced Technology Vehicle (ATV) and seven experiments. Final agreements will be negotiated and work initiated on these projects in FY 1999. Upon successful completion of negotiations with Boeing, the industry partner in the pending ATV cooperative agreement, the ATV design effort will begin in earnest. Also during FY1999, the X-40A vehicle, which has been part of an Air Force-sponsored flight test program, will be prepared for unpowered approach and landing tests as part of the ATV program. In FY 2000, the ATV will pass its critical design review, and fabrication of the flight vehicle will begin. Also, approach and landing tests of the X-40A will begin at Edwards AFB in FY2000.

Advanced Space Transportation Program (ASTP)

RLV Focused technologies were competitively selected in FY 1998 under NRA 8-21, Cycle 1, to support the decision to begin development of a next generation RLV. Selected technologies include: electron beam curing of polymer matrix composite tanks; composite joining technologies; integrated cryogenic tank and thermal protection system (TPS) hot structure; light-weight metallic TPS concepts and their fabrication; durable blanket TPS; high-temperature, integrated structures; advanced proton exchange membrane (PEM) fuel cells; and lightweight, long-life thrust cell propulsion components. RLV Focused technology development will be completed in FY 2000 to support the decision to begin development of a next generation RLV. Electron beam composite curing, propellant densification, an advanced metallic TPS array, a PEM fuel cell prototype, and lightweight composite propulsion components will be demonstrated.

The Small Payload Focused (Bantam) project conducted a small payload launch conference that validated the need to reduce the cost of small payload launch capability. System preliminary designs of four concepts were completed. The projected launch cost using low-cost design methods and existing technology ranged from $4M to $5M -- confirming the need for advanced reusable technology development to enable the target cost of $1.5M per launch of 150 kg payloads. The Bantam project has been restructured to focus on advanced reusable technology development and system analysis leading to flight experiments as technology matures. Flight experiments will be conducted within the Pathfinder program. A significant portion of FY 1998 Bantam funding will be applied to FY 1999 due to the project restructuring. In FY 1998, several low-cost Bantam component technologies were successfully demonstrated. A low-cost turbopump was designed, fabricated and assembled that will reduce the Fastrac engine turbopump cost by a factor of three. Bench verification testing of a rocket engine controller based on a Chrysler automotive computer was completed. A modular propulsion avionics suite was delivered and is ready for bench testing. A PC-based launch control and mission planning system was demonstrated in bench tests. NASA continues to cooperate with the Air Force to develop a low-cost upper stage demonstration under the Bantam project using hydrogen peroxide and jet propellant (JP). Engine injector testing was initiated and compatibility tests are being conducted for hydrogen peroxide composite tanks.

In FY 1999 a large percentage of required Small Payload technologies are being funded under the Core Airframe and Core Propulsion investment areas because they are applicable to medium and heavy payload launch systems as well. Technology plans and roadmaps developed by an inter-Center team of experts in structures and materials, thermal protection systems, cryogenic tanks, propulsion, operations, and avionics and power systems will be implemented. Detailed system analysis of several promising small-payload launch concepts will be conducted and used to focus the technology development efforts. Enabling technologies for specific small-payload concepts will also be initiated.

In FY 2000, the results of these technology demonstrations and system level analyses of multiple concepts will support concept down-selection. Technologies that are concept specific will be completed and viable concepts will be selected for further focused technology development, including potential flight demonstration. Technology development that supports multiple concepts will continue toward completion in FY 2002.

Hybrid Focused technology development was de-scoped in FY 1998 to eliminate four pump-fed 250,000-pound-thrust (250K) motor tests. Following Congressional direction in FY 1999 pump-fed motor tests were re-instituted and the tests are now planned in FY 2000.

In FY 2000, all of the 250K motor testing is planned for accomplishment at the Stennis Space Center. In addition to the large scale 250K motor tests, subscale testing of peroxide hybrid motors is planned to develop the necessary design data needed for potential upper stage applications of hybrid technology for future Bantam missions. A large-scale sounding rocket demonstration is also planned at Wallops Flight Facility as a proof of concept leading to commercial application of hybrid technology to NASA's recurring sounding rocket missions.

The **NSTAR Focused Project** completed assembly and flight qualification testing of the NSTAR flight experiment and the flight unit was delivered. The launch of Deep Space 1 was accomplished in October 1998, and as of January 5, 1999, the engine technology has performed well, having produced thrust for over 850 hours in space, well beyond the 200-hour minimum success criterion. Life testing and anomaly resolution for the NSTAR flight experiment will continue throughout FY 1999, with anomaly resolution activities to be completed by the end of FY 2000.

The **In-Space Focused** technology project continued work on solar thermal propulsion technologies in FY 1998 that could lead to a flight demonstration. Structural dynamic testing in a flight environment simulation was completed for the full-scale inflatable solar concentrator. The secondary concentrator was manufactured and delivered by GRC. The solar thermal engine module was delivered. In addition, studies were completed to support applications for an electrodynamic tether propulsion concept. Work was initiated to design, develop and demonstrate critical solar-electric propulsion technologies. The design of an experimental high-power Hall-effect thruster has been completed and characterization will begin in FY 1999. Additionally, integration of a Russian-designed 1.5 kW Hall-effect thruster was completed. Delivery of an engineering-level 10-kW Hall-effect thruster will occur in FY 1999.

In FY 2000, high-power electric propulsion, long-term cryogenic propellant storage and non-toxic propulsion systems will continue to be pursued. Advanced concepts that utilize solar thermal energy, tethers and other off-board energy sources will also be pursued. Key electric propulsion technologies that will be examined include: long-life cathodes; power processing designs; propellant feed systems; and lightweight systems integration. Endurance testing of the engineering-level 10-kW Hall-effect thruster and breadboard designs of advanced power processing units will be completed.

Core Propulsion technology was focused on testing three air-breathing, rocket-based-combined-cycle concepts in FY 1998. The trajectory simulation facility at the General Applied Sciences Laboratory, Inc. (GASL) was completed and trajectory simulation mode was successfully tested for the first time in this country. Inlet tests on two RBCC concepts were completed at the GRC. Rocket thruster fabrication and testing was completed for two of three concepts. The third thruster concept has been delayed because of fabrication difficulty. Direct-connect testing was completed in RAM and SCRAM operating modes at GASL. Two RBCC concepts are currently installed in the GASL free jet facility. Testing on one concept is near completion. Testing on the second concept is beginning and will be completed in early FY 1999. Experimental studies at Pennsylvania State University and the University of Alabama, Huntsville are continuing in support of the engine concepts. A flight-weight RBCC propulsion system design will be conducted through FY 1999. Vehicle systems analysis will provide data to support a flight experiment decision by the end of FY 1999.

In FY 2000, the RBCC flight-weight engine design and vehicle system analysis will be completed. A decision to continue focused technology development toward a flight experimental vehicle will be made. Technology development for highly reusable propulsion systems will continue at a low funding level through FY 2000. Investments in advanced rocket propulsion technologies will support planned government/industry IHPRPT demonstrators and component technology developments to support the Small Payload

Focused investment area. Technologies to be examined include: ceramic matrix composites for turbomachinery components and nozzles; metal matrix composites for housings and internal components; advanced altitude compensating nozzles; advanced fuels; analytical design and life prediction techniques. RBCC design and testing will continue towards flight weight designs and a low-cost development approach for long life propulsion systems will be pursued. Investments in advanced rocket propulsion technologies will continue in ceramic matrix composites for turbomachinery components and nozzles, metal matrix composites for housings and internal components, smart valves, and analytical design tools and life prediction techniques. A long life propulsion system will be demonstrated in FY2000.

Core Airframe technology development was initiated at a very low funding level in FY 1998. Limited investments were focused on structures and materials, cryogenic tanks, thermal protection systems, and avionics/operations technologies. Systems analysis has been initiated to support the evaluation of advanced air-breathing launch vehicle concepts to support the RBCC decision in FY 2000. In FY 1999, investments will continue in structures and materials, cryogenic tanks, thermal protection systems (TPS), avionics/operations, and system analysis, design and integration in support of the Small Payload focused investment area.

In FY 2000, development and demonstration areas in airframe systems will include: high-temperature, impact-resistant thermal protection systems; ultra-high-temperature leading edges; smart thermal protection systems; ultra-high temperature polymer matrix composites for airframes and propulsion systems; high-energy-density power systems; robust guidance, navigation and control systems; and advanced ground and range operations systems. The technologies are critical to the development of a low-cost small and medium/heavy reusable launch capability. Technologies will support potential flight demonstrations in FY 2002.

In the **Space Transportation Research** program, feasibility issues associated with revolutionary propulsion concepts continue to be evaluated at MSFC, GRC and JPL in cooperation with other federal agencies. The antimatter-triggered fusion research has continued to show progress towards the eventual objective of trapping, cooling and transporting antiprotons from Fermi Labs to the Air Force Shiva-Star Facility for micro-fusion experiments. The project will also continue to assess the feasibility of a total-charge-transfer cathode for high-power plasma thrusters that is an order of magnitude beyond the current state-of-the-art, and will continue to investigate the concept of a dense plasma focus thruster using aneutronic fuels. Two pulse detonation engine test articles have been constructed and have begun initial tests to demonstrate the engineering feasibility of rocket engines based on this promising technology. Short track tests of a magnetic levitation breadboard were conducted to investigate its potential application for launch assist. Free-flight tests of a laser-powered launch vehicle were conducted using a ground-based laser on a small test article.

In FY 1999, the Space Transportation Research projects will pursue proof-of-concept research in technology areas that may lead to significant reductions in the cost of access to space or may enable new space missions. The testing activities associated with the pulse detonation rocket engines and the magnetic levitation breadboard will be transferred to the Small Payload Focused program for the next phase of testing. Exotic fuels research on strained ring hydrocarbons, initiated jointly with NASA GRC and the Air Force Research Lab at Edwards, will test fire several high-performance hydrocarbons in a small rocket motor. Solid hydrogen experiments will continue at GRC, aimed at controlling high-energy-density fuels based on atomic recombination energy. Experiments and analyses will continue on very advanced, high-power electric thrusters and advanced energy concepts. The antimatter-triggered fusion research will continue toward the eventual objective of acquisition, storage, and experimentation. Analyses and experiments will be performed to determine the feasibility of some potential fusion propulsion concepts. Safe, low-cost nuclear propulsion concepts will continue to be analyzed and some experiments, without nuclear material, will be conducted to evaluate potential performance enhancements. Analyses will continue to investigate avenues for interstellar missions and their precursors. Proposals will be solicited and evaluated for low-cost breakthrough propulsion physics experiments.

In FY 2000, Space Transportation Research will be guided by peer review of the most promising breakthrough concepts. The first peer review was conducted in FY 1998 and recommended focusing Space Transportation Research on advanced high-energy-density fuels, antimatter concepts and other breakthrough propulsion physics. Space Transportation Research will continue to pursue propulsion concepts that have the potential for interstellar travel.

Engineering Capability Development continues to fund utilization, maintenance, and productivity upgrades for the premiere national facilities at LaRC, GRC and ARC required to accomplish the goals of ASTP and RLV. FY 2000 funding for this effort will be shared by multiple programs.

SCIENCE. AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY — **COMMERCIAL TECHNOLOGY/SBIR**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Commercial Programs	25.200	33.700	29.200	SAT 4.3-2
Technology Transfer Agents	20.000	12.200	5.800	SAT 4.3-5
Small Business Innovation Research Programs	101.500	94.500	97.500	SAT 4.3-9
Total	146.700	140.400	132.500	
Johnson Space Center	13.325	16.452	16.800	
Kennedy Space Center	6.470	7.822	5.100	
Marshall Space Flight Center	30.620	21.398	21.800	
Stennis Space Center	4.107	4.306	4.000	
Ames Research Center	16.733	13.364	12.900	
Dryden Flight Research Center	2.916	3.312	3.400	
Langley Research Center	18.451	17.648	17.600	
Glenn Research Center	20.107	19.799	15.500	
Goddard Space Flight Center	27.425	26.391	24.100	
Jet Propulsion Laboratory	4.200	2.220	9.200	
Headquarters	2.346	7.688	2.100	
Total	146.700	140.400	132.500	

BASIS OF FY 2000 FUNDING REQUIREMENT

COMMERCIAL PROGRAMS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Commercial Programs, subtotal	19,400	28,700	29,200
Special Interest Projects	5,800	5,000	--
Total Commercial Programs	25,200	33,700	29,200

PROGRAM GOALS

Commercial Programs facilitates the transfer of NASA inventions, innovations, discoveries or improvements developed by NASA personnel or in partnership with industry/universities to the private sector for commercial application leading to greater U.S. economic competitiveness. Accordingly, the goal of Commercial Programs is to share the harvest of NASA's technology programs with the U. S. industrial/scientific community. The goal encompasses the commercialization of technology developed in all the Agency's Enterprises, in past as well as current programs. The NASA Commercial Program mission includes a variety of mechanisms for achieving its goals: partnerships with industry/academia; federal/state/local alliances; emphasis on commercialization in new R&D procurements; electronic commerce; training and education of NASA employees/contractors; employee accountability; and application of performance goals/metrics.

STRATEGY FOR ACHIEVING GOALS

Changes in national R&D investment guidelines have elevated commercial technology transfer to a primary NASA mission. NASA's Agenda for Change, approved by Administrator Goldin in July 1994, is the Agency's blueprint for achieving this mission. Commercial Programs introduces a new way of doing business that involves a mix of practices/mechanisms which enable the Agency to more closely align its way of doing business with that of the private sector. The common denominator in these practices is technology partnerships. Technology partnerships are business arrangements among the government, industry, and/or academia wherein each party commits resources to the accomplishment of mutually agreed upon objectives and shares the risks and rewards of the endeavor. At the end of FY 1998, NASA has succeeded in accomplishing the National Performance Review goal of 10 to 20 percent of the NASA R&D budget in commercial technology partnerships with industry by achieving almost 16%.

The success of Commercial Programs is accomplished through:

- An extensive outreach program (technology dissemination and marketing);
- An electronic commerce/information network (via the Internet) that greatly facilitates the transfer of technology and allows very efficient implementation of our technology business contacts and services;
- Training and education of NASA employees to emphasize program relevance to national needs and to facilitate program implementation; and
- the establishment of metrics that address the day-to-day management processes as well as bottom-line results.

The Agenda for Change marked the beginning of NASA's new focus, management commitment, and employee empowerment to improve NASA's contributions to America's economic security as a vital by-product of NASA's aeronautics and space missions.

SCHEDULES & OUTPUTS

Expand training program for NASA R&D program managers. Plan: April 1998 Actual: September 1998	Expanded training to help foster the Agency's internal culture change necessary to increase technology transfer and partnerships with private industry. Initiated, via the Internet, distance learning pilot program to enhance cost-effective training opportunities. Internet image stream took longer to set up than expected.
Assess approximately 100% of NASA technology for commercial application. FY 1999 Plan: December 1998 Actual: December 1998	In FY98 we assessed over 8,800 activities to which NASA obligated over $10 billion. This represented approximately 85% of NASA's programs and activities. 1,169 new technologies and innovations were identified and evaluated for commercial application. Current inventory of technology will be reviewed, assessed and rated for commercial potential.
FY 2000 Plan: December 1999	Current inventory of technology will be reviewed, assessed and rated for commercial potential.
Increase percentage of NASA R&D Invested in Commercial Partnerships with a goal of achieving 15-20% Plan: December 1999	Show steady improvement toward reaching 20%, providing assurance that we can meet the upper range of the National Performance Review goal for the Agency. Current performance level is 16 percent.
Expand training program for NASA R&D program managers. Plan: September 1999	Expand the distance learning and classroom training program to several training sessions with increased participation to help foster the Agency's internal culture change and further improve technology transfer performance.

ACCOMPLISHMENTS AND PLANS

In FY 1998, the emphasis was on increasing commercial partnerships with industry and continuing refinement of the technology and partnership database, updating it to include new Agency contracting efforts and to describe new technologies that are to be made public on the electronic network. The Agency also improved a new information network for commercial technology transfer. The partnership goal was achieved, and there was an increase in R&D partnerships from 10 to approximately 16 percent of the relevant NASA R&D program. In addition, the commercial technology program significantly improved the technology information available to the public and the efficient management of the technology database. The number of technologies made available to the business community and offered for partnership via the TechTracS electronic commerce system has increased over 30% -- from 15,000 in January 1996 to about 20,000 in September 1998.

In FY 1999 and FY 2000, the emphasis will be on increasing commercial partnerships with industry and continuing refinement of the technology and partnership database, updating it to include new Agency contracting efforts and to describe new technologies that are to be made public via the electronic network. The Agency's goal for these years will be to increase the percentage of the NASA R&D budget in commercial partnerships with industry to 16-18 percent in FY 1999 and approach 20 percent in FY 2000. The FY 1999 funding level for Commercial Programs also includes funds to administer the SBIR program, with emphasis placed on improving services to small businesses. In FY 1999 and FY 2000, NASA will continue to utilize and improve the Internet as an electronic marketplace for NASA technology assets, facilitating technology transfer and commercialization opportunities between U. S. industry and NASA. In addition, a series of training opportunities focused on the commercial technology strategy and its implementation actions will be expanded within NASA's management training program.

BASIS OF FY 2000 FUNDING REQUIREMENT

TECHNOLOGY TRANSFER AGENTS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Technology Transfer Agents, subtotal	7,800	7,200	5,800
Special Interest Projects	12,200	5,000	--
Total Technology Transfer Agents	20,000	12,200	5,800

PROGRAM GOALS

The goal of Technology Transfer Agents is to facilitate the transfer of NASA and other federally sponsored research and technology (and associated capabilities), to the U. S. private sector for commercial application. The purpose of this program goal is to enhance U. S. industrial growth and economic competitiveness.

STRATEGY FOR ACHIEVING GOALS

In conformance with Congressional direction, NASA has funded the NTTC at Wheeling Jesuit College in West Virginia since 1990 to serve as a national resource for the transfer and commercialization of federal research and technology. A key, on-going strategy is to align and integrate NTTC operations with the NASA Commercial Technology Programs in support of the NASA Commercial Technology Mission/Agenda for Change. This strategy provides a foundation upon which the NTTC may fulfill its national role through technology transfer programs funded by other federal agencies and the provision of cost-recovery products and services. Accordingly, NASA has facilitated the involvement of other federal agencies to leverage and extend NTTC capabilities funded by NASA and has enabled the NTTC to implement cost-recovery activities in support of the overall federal technology transfer mission.

In accordance with the NTTC's national role and the NASA Commercial Technology Mission/ Agenda for Change, the NTTC performs four core roles: (1) Serve as a national gateway for federal technology transfer and commercialization, assisting U. S. industry to locate and access NASA and other federally-sponsored technology resources and sources of technical/business assistance; (2) Assess NASA and other federal technologies for commercial potential, and facilitate partnerships for technology commercialization; (3) Develop and deliver professional-level training in technology transfer and commercialization for NASA, federal agencies and other public and private sector audiences; and (4) Promote U. S. industry awareness and utilization of NASA and other federally sponsored research and technology resources available for commercial purpose.

In FY 2000, in recognition of the NTTC's maturing operations and services, the implementation of the NTTC program will transition from a cooperative agreement into a contractual funding instrument. A contract is an appropriate vehicle for the performance and delivery of high-quality technology transfer and commercialization services that directly support the NASA Commercial Technology Mission. This will further improve the effectiveness of the NTTC program and foster the privatization of the NTTC.

SCHEDULES & OUTPUTS

In partnership with NASA, implement six national conferences, including Tech 2008 Plan: September 1998 Actual: September 1998	Further the Agenda for Change goal of marketing NASA's capabilities. Tech 2008 was completed during the first quarter FY 1999; six additional national technology conferences were conducted in FY 1998: Medical Design and Manufacturing, Society of Automotive Engineers, National Design and Engineering Show, SAMPE, ISA and Tech 2007.
In partnership with NASA, target specific industries and companies who may benefit from NASA technology and develop marketing strategies to those industries and firms. Plan: September 1998 Actual: September 1998	Supports the Agenda for Change goal of marketing NASA's capabilities. The results will be establishing R&D partnerships with industry leading to new products and services based on NASA technology. In conjunction with the NTTC, NASA's marketing plan is comprised of targeting a series of four national industry sectors: manufacturing, materials, medical devices, and sensors /instrumentation. During FY 98, NASA/NTTC implemented its first public service message campaign targeting each of these sectors. This effort has produced valuable business leads for the NASA Centers. Since NASA started this effort, the number of technology inquiries has grown from 1,248 in FY 96 to over 8,200 in FY 98. In addition, U.S. Ad Review, a nationally recognized advertising review board, recognized NASA as having one of the best marketing campaigns in the country. NASA also launched a new strategy for turning trade shows in which NASA was an exhibitor into deal- making events. NASA now pre-qualifies companies prior to the show and sets up business meetings between the inventor and the interested company. At the three trade shows where this strategy was conducted, at least 50% of the technologies showcased received excellent leads. These leads are currently being followed up by NASA Centers with the goal of an R&D partnership or a license. Modeled along efforts pursued by the private sector, NASA's strategy is focused on integrating public relations, public service messages, direct mail, and trade shows to convey the message that NASA is a technology resource that companies can fully utilize to their advantage.
In partnership with NASA, develop and deliver a professional training program for US industry. Plan: September 1998 Actual: September 1998	Developed three courses for a professional training program for US industry. The goal is to enable companies to successfully commercialize NASA technology.
In partnership with NASA, deliver Commercial Technology training courses. Plan: September 1999	Supports the Agenda for Change goal of fostering an internal Agency culture change and implementation of required skills and best practices through training and education. Ten courses will be delivered in FY 1999.

In partnership with **NASA,** generate and maintain broad industry interest in **NASA** technologies and increase the number of qualified referrals for **NASA** technology Plan: September 1999	Service a minimum of 16,000 inquiries and produce at least 750 qualified referrals for **NASA** technologies in FY 1999.
Increase the Assessment/ Partnering between **NASA** and Industry Plan: September 1999	Complete 25 in-depth commercialization potential assessments of **NASA** technologies, facilitate venture financing for 10 **NASA** SBIR firms, and qualify and assist licensing/partnering agreements for 10 **NASA** technologies in FY 1999.
In partnership with **NASA,** deliver Commercial Technology training courses. Plan: September 2000	Supports the Agenda for Change goal of fostering an internal Agency culture change and implementation of required skills and best practices through training and education. Ten courses will be delivered in FY 2000.
In partnership with **NASA,** maintain broad industry interest in **NASA** technologies and maintain the number of qualified referrals for **NASA** technology. Plan: September 2000	Service a minimum of 16,000 inquiries and produce at least 750 qualified referrals for **NASA** technologies per year in FY 2000.
Maintain the Assessment/ Partnering between **NASA** and Industry Plan: September 2000	Complete 25 in-depth commercialization potential assessments of **NASA** technologies, facilitate venture financing for 10 **NASA** SBIR firms, and qualify and assist licensing/partnering agreements for 10 **NASA** technologies in FY 2000.

ACCOMPLISHMENTS *AND* PLANS

In cooperation with **NASA,** the NTTC has implemented marketing and outreach activities (e.g. public service announcements, trade shows, direct mail, publications and Internet/Web-sites) with **NASA** to generate U. S. industry awareness of, and interest in. utilizing and commercializing **NASA** technologies. NTTC marketing and outreach activities, in FY 1998, resulted in over 16,000 inquiries for **NASA** technology, which the NTTC serviced and screened: resulting in over 600 qualified referrals for **NASA** technologies. The NTTC has also teamed with **NASA** to deliver **18** training events designed to improve the knowledge and application of skills and methods for technology transfer and commercialization across **NASA.** The NTTC continued, in FY 1998, to develop, test, and implement distance learning and Internet-based training activities, further establishing its role within the NASA community as a leading resource for technology transfer/commercialization training. In addition, the NTTC implemented new capabilities and activities, including the piloting of technology commercialization reviews in FY 1998, to perform market and technology assessments of NASA-sponsored technologies, and to facilitate the technology commercialization process. The NTTC will build upon these activities and capabilities in FY 1999 and FY 2000 to perform its four key roles for NASA as well as leveraging and extending NASA-funded capabilities to implement cost-recovery products/services and to conduct activities funded by other federal agencies.

The NTTC is currently in its final year under a five-year cooperative agreement with NASA. NASA will be assessing the NTTC's performance and capabilities relative to the NASA Commercial Technology Mission during the remainder of the agreement to determine the requirements and appropriate contractual funding instrument for the planned continuation of the program in FY 2000 and beyond.

In conformance with FY 1996 Congressional direction, NASA awarded and fully-funded in FY 1996 a four-year Cooperative Agreement to Montana State University (MSU) to establish and operate a rural technology transfer and commercialization center (known as the NASA/MSU TechLink Center) to assist companies and targeted industries in Montana, Idaho, N. Dakota, S. Dakota and Wyoming to utilize and commercialize technologies from NASA, federal laboratories, and universities. The Center provides services to targeted industries (natural resource-based industries, specifically agriculture, mining; forest/wood products, technology-based industries, including environmental services, photonics, and electronics/communications) directed towards creating technology partnerships with NASA and other federal/university technology sources and fostering successful technology commercialization and business development within the upper plains region. In FY 1998, the Center facilitated eight technology partnerships between and NASA and U.S. firms, and is currently working to assist the formation of 15 technology partnerships in FY 1999. During FY 2000, the terms of the cooperative agreement fulfilled and the agreement will be completed. The TeckLink is currently seeking to diversify funding with support from other federal agencies and industry.

BASIS OF FY 2000 FUNDING REQUIREMENT

SMALL BUSINESS INNOVATION RESEARCH PROGRAMS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Small Business Innovation Research....................................	101,500	94,500	97,500

PROGRAM GOALS

The goals of NASA's Small Business programs are to promote the widest possible award of NASA research contracts to the small business community as well as to promote commercialization of the results of this research by the small business community.

STRATEGY FOR ACHIEVING GOALS

Established by Congress, the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) programs help NASA develop innovative technologies by providing competitive research contracts to U. S. owned small businesses. The program is structured in three phases:

Phase I is the opportunity to establish the feasibility, technical merit, and NASA mission need of a proposed innovation. Selected competitively, Phase I contracts have a term of six months and currently do not exceed $70,000.

Phase II is the major R&D effort in SBIR. The most promising Phase I projects are selected to receive contracts worth up to $600,000 and having a term of up to two years. Approximately 50 percent of Phase I projects are approved for Phase II.

Phase III is the completion of the development of a product or process to make it marketable. SBIR program funding cannot used to support the Phase III program. Private sector investment and sales of products and services based on the SBIR technology is the usual source of Phase III funding.

The FY 1998 NASA SBIR solicitation included 28 major topic areas divided into 118 sub-topics. The description of each of these sub-topics is developed by various NASA installations to include current and foreseen Agency program needs and priorities. NASA typically receives over 2,000 proposals. For each solicitation, proposals are evaluated by the NASA field centers for scientific and technical merit, key staff qualifications, soundness of the work plan, and likelihood of commercial application. NASA Headquarters (HQ) program offices provide additional insight regarding commercial feasibility, program balance, and critical Agency requirements. Selections are made by NASA HQ, based upon these recommendations, and other considerations. During FY 1998, there were 340 Phase I awards.

NASA continues to utilize the Internet extensively to administer the program. NASA also provides information for public access via a bulletin board service and other Internet information servers. Moreover, NASA continues to increase it's use of the Internet and information technology in it's operational processes including the development of the technical solicitation sub-topics; for public release of the solicitation in a variety of electronic formats; and for proposal evaluation. The end-to-end electronic solicitation process is serving as a resource not only within NASA, but is being viewed as a prototype for other government agencies.

Several other innovations continued to strengthen small business programs. External evaluation of each proposal's ultimate commercial potential is now a foundational part of the selection process. In addition, a comprehensive survey of past SBIR projects' Phase III commercialization and/or mission application continues to be conducted. The information from the review/survey will be used to identify critical predictors of commercial viability and, therefore, be used to increase the commercialization effectiveness of the program. Finally, the process of mapping several sub-topics into specific NASA mission applications continues to be a focus for strategic planning activities. The intent is to more closely tie the SBIR program with the primary mission needs of each NASA Enterprise.

The NASA SBIR program has contributed to the U. S. economy by fostering the establishment and growth of over 1,100 small, high technology businesses. More than 430 private ventures have been initiated based on NASA SBIR programs. Over one hundred of the SBIR Phase II firms have produced Phase III agreements generating at least $1 million per firm in new revenues.

SCHEDULES & OUTPUTS

The program supports schedules and outputs in multiple areas. The program must be implemented in a manner that maximizes the potential for success. Therefore, a set of metrics for successful completion of each solicitation (Pre-solicitation, Solicitation, Selection/Award, and Post-Award) activity continues to be refined and used to assess the operational and management performance of the program. In addition, NASA is in the process of obtaining commercialization metrics (revenue; jobs creation) from previous SBIR awardees in order to better measure the contribution of the SBIR Program to the overall success in meeting the Agency's commercialization goals.

Select and announce new SBIR Phase I awards resulting from the FY 1997 solicitation Plan: February 1998 Actual: February 1998	Initiates awards for new solicitation. All supporting activities completed successfully and as planned.
Complete development and issue the FY 1998 SBIR solicitation. Plan: April 1998 Actual: April 1998	Necessary to ensure the success of the FY 1998 research program. All supporting activities completed successfully.

Select and announce new SBIR Phase I awards resulting from the FY 1998 solicitation. Plan: November 1998 Actual: October 1998	Initiates awards for new solicitations. All supporting activities completed successfully; all Program planned activities successfully scheduled.
Select and announce new SBIR Phase II awards resulting from the FY 1997 solicitation. Plan: October 1998 Actual: December 1998	Initiates follow-on awards resulting from prior Phase I results. All supporting activities completed successfully and as planned.
Complete development and issue the FY 1999 SBIR Phase I solicitation. Plan: April 1999	Necessary to ensure the success of the FY 1998 research program. Provide initial assessment of commercial success of FY 1983 - 1994 awardees and overall program performance.
Select and announce new SBIR Phase II awards resulting from the FY 1998 solicitation. Plan: November 1999 Revised: September 1999	Initiates follow-on awards resulting from prior Phase I results.
Select and announce new SBIR Phase I awards resulting from the FY 1999 solicitation. Plan: December 1999 Revised: October 1999	Initiates awards for new solicitation.
Perform commercial assessment FY 1998 outcome success and complete development the FY2000 SBIR solicitation Plan: April 2000	Ensure the success of the FY 1998 research program. Perform initial assessment of commercial success and overall performance of program
Select and announce SBIR Phase II awards resulting from the FY 1999 solicitation. Plan: August 2000	Initiates follow-on awards resulting from prior Phase I results;

ACCOMPLISHMENTS AND PLANS

In accordance with the Small Business Innovation Development Act of 1982, the actual SBIR funding level for the Agency is determined based on the results of a detailed analysis of the actual obligations for the most recent fiscal year that data is available. For FY 1998 and FY 1999, the funding levels are based on actual data. For FY 2000, the funding level shown for SBIR is a placeholder that is used for planning purposes only. In early FY 2000, the Office of the Comptroller will perform a detailed assessment on the Agency's most recent actual data. If the results of the assessment conclude that the actual SBIR funding level varies from the budgeted amount, that change will be reflected in the Agency's initial operating plan to Congress.

In FY 1998, activities have been completed to secure alignment of the topic and subtopics in the SBIR programs with Enterprise needs, increase commercialization metrics collection and more adequately measure progress in commercializing technology.

The performance metrics are based on initial results of a survey being conducted utilizing an OMB approved data collection instrument and methodology. The survey continually captures various measures of commercial activity associated with NASA funded SBIR technology. An initial program performance assessment is expected to be available in March 1999.

FY 1999 and FY 2000 solicitations will include new SBIR Phase I and Phase II awards, and continued emphasis on and evaluation of commercial successes and successful applications to NASA programs. By December 1998, the 1997 Solicitation Phase II awards and 1998 Solicitation Phase I awards will be announced and under contract or in contract negotiation. In FY 1999, announcements will be made for the 1998 Solicitation Phase II awards and FY 1999 Phase I awards.

SCIENCE, AERONAUTICS, AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT | **MISSION COMMUNICATIONS SERVICES**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Ground Networks	221,600	211,200	228,800	SAT 5-4
Mission Control and Data Systems	148,100	143,100	150,500	SAT 5-11
Space Network Customer Services	31,100	25,700	27,000	SAT 5-21
Total	400,800	380,000	406,300	
Distribution of Program Amount by Installation				
Johnson Space Center	6,700	5,500	8,800	
Marshall Space Flight Center	2,100	300	300	
Dryden Space Flight Center	14,600	12,600	14,900	
Glenn Research Center	9,800	10,100	10,100	
Goddard Space Flight Center	205,600	187,400	192,000	
Jet Propulsion Laboratory	159,400	161,000	174,900	
Headquarters	2,600	3,100	5,300	
Total	400,800	380,000	406,300	

PROGRAM GOALS

The Space Communications goal is to provide high quality, reliable, and cost effective space operations services which enable Enterprise mission operations. Reliable electronic communications are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Space Operations Management Office (SOMO), located at the Johnson Space Center, in Houston, Texas manages the telecommunication, data processing, mission operations, and mission planning services needed to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. The SOMO is committed to seeking and encouraging commercialization of NASA operations services and to participating with NASA's strategic enterprises in collaborative interagency, international, and commercial initiatives. As NASA's agent for space operations services, the SOMO seeks opportunities for using technology in pursuit of more cost-effective solutions, highly optimized designs of mission systems, and advancement of NASA's and the nation's best technological and commercial interests. The content described in this section represents the Mission Communications Services portion of the SOMO responsibilities.

The Mission Communications Services segment of NASA's Space Communications program is composed of Ground Networks, Mission Control and Data Systems, and Space Network Customer Service. These programs establish, operate, and maintain NASA ground networks, mission control, and data processing systems and facilities to provide communications service to a wide variety of flight programs. These include deep space and Earth-orbital spacecraft missions, research aircraft missions, and sub-orbital flights. Mission support services such as orbit and attitude determination, spacecraft navigation and maneuver support, mission planning and analysis and other mission services are provided. New communications techniques, standards, and technologies for the delivery of communication services to flight operations teams and scientific users are developed and applied. Agency spectrum management and data standards coordination for NASA are conducted under this program.

STRATEGY FOR ACHIEVING GOALS

The Space Communications program provides command, tracking, and telemetry data services between the ground facilities and flight mission vehicles. This includes all the interconnecting telecommunications services to link tracking and data acquisition network facilities, mission control facilities, data capture and processing facilities, industry and university research and laboratory facilities, and the investigating scientists. The program provides scheduling, network management and engineering, pre-flight test and verification, flight system maneuver planning and analysis. The program provides integrated solutions to operational communications and information management needs common to all NASA strategic enterprises. The Mission Communications Services program, one part of NASA Space Communications program, provides systems and services to a large number of NASA missions, including planetary and interplanetary missions; human space flight missions; near-Earth and Earth-orbiting missions; sub-orbital and aeronautical test flights.

The range of telecommunications systems and services are provided to conduct mission operations, enable tracking, telemetry, and command of spacecraft and sub-orbital aeronautical and balloon research flights. Additionally, services and systems are provided to facilitate data capture, data processing, and data delivery for scientific analysis. The program also provides the high-speed computer networking, voice and video conferencing, fax, and other electronic mail services necessary to administer NASA programs. These communications functions are provided through the use of space and ground-based antennas and network systems, mission control facilities, computational facilities, command management systems, data capture and telemetry processing systems, and a host of leased interconnecting systems ranging from phone lines and satellite links to optical fibers.

The program provides the necessary research and development to adapt emerging technologies to NASA communications and operational requirements. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. NASA's flight programs are supported through the study and coordination of data standards and communication frequencies to be used in the future.

Many science and exploration goals are achieved through inter-agency or international cooperation. NASA's Space Communications assets are provided through collaborative agreements with other U.S. Government agencies, commercial space enterprises, academia, and international cooperative programs. Consistent with the National Space Policy, NASA will procure commercially available goods and services to the fullest extent feasible, and will not conduct activities with commercial application that preclude or deter commercial space activities. Rather, NASA will develop selected technologies which leverage commercial investments and enable and foster the use of existing and emerging commercial telecommunications services to meet NASA's space communications needs. These are all parts of the strategic approach to providing the vital communications systems and services common to all NASA programs and to achieve compatibility with future commercial satellite systems and services.

Efforts are continuing to consolidate and streamline major support contract services. In FY1996, a plan to transition to a consolidated space operations contract began and has been implemented in two distinct phases. In FY 1997, two short-term, fixed-price study contracts were awarded to develop an Integrated Operations Architecture (IOA) approach to consolidate space operations activities across the Agency. On October 1, 1998, a Consolidated Space Operations Contract (CSOC) was competitively awarded to the Lockheed-Martin Space Operations Company. This contract, managed by SOMO, is a 10-year, cost-plus-award-fee (CPAF) effort that became fully operational on January 1, 1999. This consolidated, integrated approach to space operations is expected to maximize space operations resources by reducing systems overlap and duplication. Significant efficiencies and economies are expected over the life of the CSOC contract. Additional efforts will be undertaken to consider other opportunities for accelerating the National Space Policy directive that NASA privatize or commercialize its space communication operations no later than 2005.

BASIS OF FY 2000 FUNDING REQUIREMENT

GROUND NETWORKS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Deep Space Network – Systems	78,700	75,500	82,900
Deep Space Network – Operations	80,500	81,300	86,100
Spaceflight Tracking and Data Network - Systems	3,000	2,300	2,400
Spaceflight Tracking and Data Network - Operations	16,800	15,100	14,000
Aeronautics, Balloons, and Sounding Rockets - Systems	12,400	8,200	12,200
Aeronautics, Balloons, and Sounding Rockets - Operations	30,200	28,800	31,200
Total	221,600	211,200	228,800

PROGRAM GOALS

The Ground Networks program goal is to provide high quality, reliable, cost-effective ground-based tracking, command and data acquisition systems and services for NASA science and aeronautics programs. Launch, emergency communications, and landing support for the Space Shuttle is also provided by the Ground Networks facilities. The program provides for the implementation, maintenance, and operation of the tracking and communications facilities necessary to fulfill program goals for the NASA flight projects. The Ground Networks program also supports NASA programs in collaborative interagency, international, and commercial enterprises and independently provides support to other national, international, and commercial enterprises on a reimbursable basis.

STRATEGY FOR ACHIEVING GOALS

The Ground Networks program is comprised of the following elements: the Deep Space Network (DSN), managed by the Jet Propulsion Laboratory (JPL); the Spaceflight Tracking and Data Network (STDN), managed by the Goddard Space Flight Center (GSFC); the Aeronautics, Balloon and Sounding Rocket (AB&SR) tracking and data acquisition facilities managed by GSFC/Wallops Flight Facility (WFF); and the Western Aeronautical Test Range (WATR), managed by the Dryden Flight Research Center (DFRC). As the prime contractor for the CSOC, the Lockheed-Martin Space Operations Company will be responsible for providing space operational services beginning in January 1999.

Re-engineering efforts will continue on the STDN facilities, resulting in reduced operation and maintenance costs. NASA terminated S-band and C-band services at the Bermuda station in November 1998, following completion of two Space

Shuttle modifications. One permits earlier communications through the Tracking and Data Relay Satellite (TDRS) during the launch phase of the mission and the second allows onboard use of the GPS to replace the use of ground radar for Space Shuttle navigation. UHF Command services will continue on a reimbursable basis through March 1999. The UHF air-to-ground voice service remains available for Space Shuttle launch operations.

The number of missions serviced by the DSN facilities and the requirements of the individual missions will increase dramatically over the next several years. In anticipation of the increases, new antenna systems have been developed and obsolete systems are expected to be phased out or converted for alternate uses. The DSN has been reconfigured with four new 34-meter antenna systems located at Goldstone, California; Canberra, Australia; and Madrid, Spain. These 34-meter antennas will enable the expanded coverage requirements and provide simultaneous coverage of two deep space missions which are in critical phases. Currently, a 34-meter antenna transferred from the U.S. Army located at Goldstone is supporting the Solar Observatory for Heliospheric Observations spacecraft. An 11-meter antenna system has been installed at each DSN complex to provide science support for the Institute of Space and Astronautical Science (ISAS) Japanese VLBI Space Operation Program (VSOP) spacecraft.

The DSN has several on-going re-engineering efforts. These new processes allow the DSN to increase the tracking hours delivered while reducing costs. The processes include giving a single operator end-to-end control of the entire data acquisition process, redesigning systems that provide support data to allow automation and quicken response time, developing a process to better define DSN services which will allow customers to choose only the services necessary to support the mission, and providing systems support data which allow greater automation and quicker response time.

The DSN is the premier facility for tracking deep space probes and is occasionally supplemented by the facilities of other agencies or nations. NASA is actively working with industry to foster the enhancement of existing "commercial-off-the-shelf" (COTS) data processing systems to expand their applicability so that inexpensive and reliable communications services can be readily obtained for the new small-class missions. Future earth orbiting missions will be supported by commercially available tracking systems, enabled by such tools as the Very Large Scale Integration (VLSI) High-Rate Frame Synchronization and Data Extraction chips which have been transferred to industry.

New Ground Networks capabilities include two 11-meter antenna systems installed near Fairbanks, Alaska and at Svalbard, Norway to provide command and data acquisition support for the expanded number of Earth-observing missions which includes EOS AM-1 and Landsat-7. Also, the Low Earth Orbit Terminal (LEO-T) contract has been expanded to provide three autonomous 5-meter ground stations for space science mission support. The first of these systems will be installed in Puerto Rico and will be operationally ready to support the Far Ultraviolet Spectroscopy Explorer (FUSE) mission in FY 1999.

The Ground Networks program, in conjunction with other NASA elements, is demonstrating and implementing Global Positioning System (GPS) flight units on NASA-sponsored missions. This demonstration seeks to minimize future tracking and navigation activities. The Student Nitric Oxide Explorer (SNOE) mission demonstrates these new capabilities using commercial flight units as the primary source of this function. The Western Aeronautical Test Range is striving for even more efficiency as it provides NASA's capability for tracking, data acquisition, and mission control for a wide variety of flight research vehicles. The WATR provides both on-orbit and landing support to the Space Shuttle and communications with the Mir Space Station. Intense planning is underway to support the Reusable Launch Vehicle (X-33) and other wide range of vehicles with WATR resources.

NASA will pursue commercial ground tracking services for low-Earth orbit missions. Transition activities to the commercial operator will begin in FY 1999. Upon successful completion of transition activities, the 26-meter subnet will be operated at a reduced level until FY 2001 in order to meet prior project support commitments. The DSN will return to servicing only deep space missions, highly elliptical Earth orbiting missions, launch and early orbit phase, ground-based radio astronomy, and planetary radar astronomy activities.

SCHEDULE AND OUTPUTS

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Current	Plan
Deep Space Network					
Number of NASA missions	45	45	51	52	51
Number of hours of service	92,000	90,000	94,000	92,000	84,000
Ground Network					
Number of Space Shuttle launches	7	4	6	7	8
Number of NASA/Other ELV launches	25	40	25	26	25
Number of NASA Earth-Orbiting missions	33	33	32	30	37
Number of Sounding Rocket deployments	31	27	27	30	25
Number of Balloon deployments (scientific)	26	32	26	26	26
Number of hours of service (GN Orbital Tracking)	26,000	19,300	24,000	23,750	25,200
Western Aeronautical Test Range					
Number of NASA missions	1,100	750	1,200	1,100	1,200
Number of NASA research flights	750	660	900	750	350

DSN support of NASA missions and hours of service are dictated by actual launch dates and associated mission support requirements. In the WFF area, the change in the number of NASA earth-orbiting missions reflects a net increase in the number of missions to be supported based on documented requirements. New missions to be supported include: Earth Observing System (EOS) AM-1, Quickscat, and LANDSAT-7. The other increases shown are based on the current mission model reflecting planned support. Planning and development work on major priority missions such as the X-33, Hyper-X and Linear Aerospike SR-71 Experiment consumed much of the WATR resources. The changes in research flights was due to pre-flight and ground tests for UAV's and the Linear Aerospike SR-71 Experiment LASRE.

CONSOLIDATED SPACE OPERATIONS CONTRACT (CSOC)

Phase 1 Contract Award	May 1997
Phase 2 Proposal Due	January 1998
Phase 2 Contract Award	October 1998
Phase 2 Phase-In	October-December 1998
Phase 2 CSOC In Force	January 1999

The CSOC measures of performance apply to the Ground Networks, Mission Control Data Systems, and Space Network Customer Services.

ACCOMPLISHMENTS AND PLANS

The Space Shuttle launches were successfully supported through dedicated facilities of the Spaceflight Tracking and Data Network (STDN). The continuation of this support, further enabled by the implementation of the re-engineered STDN system elements, is expected throughout FY 1999 and FY 2000.

The STDN consists of the Merritt Island Launch Area (MILA) station and the Ponce de Leon inlet annex in support of Shuttle Launch and landing activities. The aging 9-meter hydraulic antennas at MILA will be replaced with electric drive systems, capable of functioning without an operator. Efforts in support of this initiative will begin in FY 1999. Technology developed in support of receiver, exciter, and ranging subsystems will be introduced in a phased manner to replace aging subsystems at MILA and Ponce de Leon.

Wallops Flight Facility (WFF) completed the installation of the 11-meter telemetry antenna systems at the Poker Flat Research Range near Fairbanks, Alaska and at Svalbard, Norway in preparation for support of the EOS AM-1, Quickscat, and Landsat-7 missions. Ground station and network integration and certification testing will be completed in the first half of FY 1999. The contract for the LEO-T systems was modified to include the delivery of three systems to be installed at Puerto Rico, Wallops Island, and Poker Flat. These systems will all be completed in FY 1999 and will provide a cost-effective command and data acquisition capability for low earth orbit missions. NASA is planning for the future of the McMurdo Ground Station (MGS) in Antarctica. The drivers for this station are the need to provide for predictable performance of MGS in support of Launch and Early Orbit Operations (LEOP), to provide for supplemental Earth Observing System (EOS) Polar Ground Network (EPGN) support, and to pursue a mutually beneficial relationship with the Air Force with regard to improved service and cost savings/sharing. Concept definition, project plans, and approval to proceed will be sought in FY 1999.

Low Earth orbit, expendable launch vehicle, sounding rocket, and atmospheric balloon mission support will be provided by a mix of permanent and transportable command, control, data acquisition, and tracking facilities. Successful support of two Pegasus launch operations was completed including the MINISAT from a mobile range deployment to the Canary Islands. The Redstone antennas recently installed at Poker Flat and at the White Sands Missile Range have successfully supported the NASA Sounding Rocket Program. Mobile support requirements for FY 1999 include missions in Norway and Puerto Rico. Planning continues for the mobile range support of the X-33 mission in California in FY 1999.

The WFF modernization upgrade of the FPQ-6 radar was completed in FY 1998. Work will be initiated on the replacement of a range safety tool in the Wallops Range Data Acquisition and Computational System. The acquisition of commercially available and maintainable PC-based telemetry front-end processors will be completed. These systems will be common to all Wallops ground stations and will replace obsolete, custom built systems currently in use. Work on the 11-meter antenna system upgrades required to support the Advanced Earth Orbiting Satellite (ADEOS) II mission will be initiated.

The DSN supported 61 NASA-sponsored missions, including Cassini which successfully completed the first of its two Venus flybys in April 1998. Mars Global Surveyor (MGS) continued in aerobraking activities. The Japanese Planet B Mars mission was launched in July 1998. The pace of spacecraft launches for exploration of the solar system will accelerate in FY 1999 as Mars, Discovery, and other programs launch multiple new missions. The Mars 98 mission will start with a dual launch, the Mars Climate Orbiter in December 1998 and the Mars Polar Lander in January 1999. Support of the Planet-B mission enroute to Mars will continue. The NEAR spacecraft will orbit an asteroid in January 1999. The Stardust Discovery mission will be launched in February 1999 on a cometary and solar wind mission. New Millennium's DS1 mission will be launched in October to examine an asteroid (and a comet if the mission is extended). At the same time, Galileo will continue its orbital tour of the Jovian system, especially Europa, Cassini will have gravity-assist maneuvers by Earth and Venus; and support for extended missions will continue. The DSN will provide support to these missions in addition to many other Earth orbiters and launch and early orbit phase supports for both cooperative and reimbursable missions.

The 11-meter antennas are performing below expectations. DSN management has formed a tiger team to address hardware and software-deficiencies and has committed the resources needed to operate the antennas in a manual mode to achieve the required science return. The capability to receive data from two spacecraft at a single beam has been implemented. This is required because of the number of missions that will be orbiting on the surface of Mars. This implementation will allow the DSN to better use the limited number of antennas that are available. As planned, the aging DSN 34-meter standard antennas at Australia and Spain will be retired and their role assumed by the newly constructed 34-meter Beam Waveguide antennas. Decommissioning is planned for the first quarter of FY 2000. The age of the antennas and cost of year 2000 software upgrades makes continuation of operations impractical beyond that date.

The DSN began implementing architectural changes in 1998. The changes involve the upgrade and automation of the 26-meter antennas, separating their electronics from those of the 34-meter and 70-meter antennas. Additional changes included the replacement of significant parts of electronics in the 34-meter and 70-meter antennas and replacing the data processing equipment at each complex with simpler commercial components. This, combined with on-going network control modifications scheduled for completion in 1999, will lead to dramatically reduced costs of network sustaining, maintenance and operations. Automated equipment will enable a single "connection operator" at a Complex to control the acquisition of data from a spacecraft and deliver it to a project.

Western Aeronautics Test Range (WATR) at Dryden Flight Research Center (DFRC) provides communications, tracking, data acquisition, and mission control for a wide variety of aeronautics and aerospace vehicles. The WATR primarily supports the Aero-Space Technology Enterprise and also provides support to the Human Exploration and Development of Space and the Mission to Planet Earth Enterprises. Special emphasis is placed on the Revolutionary Technology Leaps and Access to Space, Provide Safe and Affordable Human Access to Space, and Expand Scientific Knowledge of the Earth System programs. WATR customers include other NASA Centers, the U.S. Army, U.S. Air Force, U.S. Navy, Federal Aviation Administration and the aerospace industry.

The WATR is part of an integrated system of facilities that includes flight simulation, aircraft in the loop ground tests, flight data calibration and analysis, post-flight data analysis and archival, and remotely piloted vehicle systems. These facilities allow the DFRC to conduct flight research on a wide variety of aircraft. The WATR is a critical safety of flight element. Periodic upgrades of WATR assets ensures that consistency and quality of support are continued and that basic capabilities are available when new, short-term requirements are presented. As new programs and projects are conducted at the DFRC, existing capabilities are configured, expanded, and upgraded as necessary.

The wide range of WATR-supported vehicles covers the entire spectrum from spacecraft through high-performance and commercial test aircraft and science platform aircraft to long-duration high-altitude, Uninhabited Aerial Vehicles (UAVs). Major aeronautics programs supported by the WATR include the F-15 Advanced Control Technology Integration Vehicle (ACTIVE), the F-18 Systems Research Aircraft (SRA), F-15-B Aerodynamic Testbed, and the Pathfinder, Altus, and Centurian UAVs. Post-flight processing of Tu-144 flight data gathered in Russia is provided in support of the agency's High Speed Research program. The WATR also supports testing of the Crew Return Vehicle (X-38), a part of the International Space Station program, and the Reusable Launch Vehicle (X-33), part of the Access to Space program. The WATR works closely with other test ranges to provide support to not only the X-33 and X-34 but also the Hyper-X (X-43A) program which will be testing new propulsion and airframe systems. More programs are in the planning stages for support in FY 2000 and beyond.

To provide the most cost effective customer service, the WATR works closely with the AFFTC to find joint solutions to range challenges. Sharing range assets to support both NASA and other Air Force programs allows an overall reduction in the amount of range instrumentation on the Edwards Air Force Base installation. The sharing of resources has reduced costs at the WATR and increased the availability of range resources for customers. This will continue to benefit both the WATR and the Air Force by providing a common range infrastructure and shared range systems to support both agencies' programs.

The Extended Test Range Alliance (EXTRA) continues to solve the difficult challenge of developing a network of both traditional and nontraditional range systems to support a number of projects such as the X-33. Examples of this include collaborative agreements where one party provides the hardware and another party provides the operators and maintenance personnel. The team consists of members of the WATR as well as members from other NASA centers and DoD facilities.

Upgrades underway in the Video Control Center (VCC) will allow for the distribution and recording of multiple video feeds from the X-33 launch pad. A more powerful camera lens will make it possible to track the X-33 during launch and also high altitude UAVs. Additional improvements have been made in the long range communication capability which has improved the air-to-ground link between research aircraft and the ground station. These same systems are also used to support the Space Shuttle.

The capability to process and display Global Positioning System (GPS) parameters was incorporated into the Mission Control Center (MCC) and used to support the F-18 Sequented Ranging Assembly (SRA). Other projects such as the UAVs have also used this new capability. The Global Real-time Interactive Map (GRIM) was upgraded to handle the added requirements of such projects as X-38, LASRE, X-36, and ERAST. The Test Evaluation Command Control System (TECCS) was installed in the MCC to provide a back-up to the GRIM. Current and future projects require even more performance from the MCC display work stations. These systems and others will continually be upgraded to meet new requirements.

The Telemetry and Radar Acquisition Processing System(s) (TRAPS) were upgraded to support four real-time Pulse Code Modulation (PCM) telemetry streams. In addition, the capability to process up to 32 streams of wide band Frequency Modulated (FM) and constant bandwidth data was incorporated into the TRAPS system. This was used successfully by the F-16 Supersonic Laminar Flow Control project and will be used by other projects in the future. Also, the capability to run the F-15 ACTIVE engine model software in real-time was demonstrated with success. Planned upgrades to the telemetry front end system are required to support such projects as X-33 and ERAST but will ultimately benefit all projects.

The relocation of the mobile systems from the Ames Research Center (ARC) to DFRC was accomplished as planned. Mobile systems will continue to be upgraded to provide a quick response rapid deployment capability within the WATR. The increase in unpiloted vehicles has placed a high demand on this type of capability. A new system is being built to replace one of the old Mobile Operations Facilities (MOFs) and will be used to support the X-33 project. The Laser Tracker will be maintained long enough to support current commitments such as the T-38 Jet Inlet Redesign and will then be removed from service.

The relocation of aircraft from the ARC to the DFRC has provided more opportunities to send real-time data to remote locations. The presentation of research data in real-time to researchers remote from DFRC is a key element to the future success of the WATR and the research missions it supports. The "Virtual Flight Research Center" and "Virtual Control Room" concepts will evolve based on work already done within the mission control community and the application of new network technology.

BASIS OF FY 2000 FUNDING REQUIREMENTS

MISSION CONTROL AND DATA SYSTEMS

	FY 1998	FY 1999 (Thousands of Dollars)	FY 2000
Mission Control - Systems	13,400	16,700	10,800
Mission Control - Operations	47,300	42,400	43,600
Data Processing - Systems	3,000	2,800	4,900
Data Processing - Operations	84,400	81,200	91,200
Total	148,100	143,100	150,500

PROGRAM GOALS

The Mission Control and Data Systems program goal is to provide high-quality, reliable, cost-effective mission control and data processing systems and services for spaceflight missions; data processing, and flight dynamics services for NASA flight projects. The program provides for data systems, telecommunications systems technology demonstrations, and coordination of data standards and communications frequency allocations for NASA flight systems. The Mission Control and Data Systems program provides for the launch and early orbit implementation, maintenance, and operation of the mission control and data processing facilities necessary to ensure the health and safety and the sustained level of high quality performance of NASA flight systems. The program provides and demonstrates key technologies and innovative approaches to satisfy Strategic Enterprises' mission needs and to maximize NASA's ability to acquire commercial services that meet its communications and operations needs. Through these efforts, the program also seeks to promote sustained U.S. economic and technological leadership in commercial communications.

STRATEGY FOR ACHIEVING GOALS

The Mission Control and Data Systems program, primarily managed by the GSFC, is comprised of a diverse set of facilities, systems and services necessary to support NASA flight projects. The Lockheed Martin Space Operations Company was awarded the Consolidated space Operations Contract (CSOC) and will be the primary contract responsible for systems engineering, software development and maintenance, operations, and analytical services beginning in January 1999.

The mission control function consists of planning scientific observations and preparing command sequences for transmission to spacecraft to control all spacecraft activities. Mission Operations Centers (MOC's) interface with flight dynamics and communications network, and science operations facilities in preparation of command sequences, perform the real-time uplink of command sequences to the spacecraft systems, and monitor the spacecraft and instrument telemetry for health, safety, and system performance. Real-time management of information from spacecraft systems is crucial for rapid determination of the condition of the spacecraft and scientific instruments and to prepare commands in response to emergencies and other unplanned events, such as targets of opportunity.

Mission control facilities operated and sustained under this program are Mission Operation Centers (MOCs) for the Hubble Space Telescope (HST) program; the International Solar Terrestrial Physics (ISTP) Wind, Polar, and Solar Observatory for Heliospheric Observation (SOHO); Rossi X-ray Timing Explorer (RXTE), TOMS-Earth Probe (EP) , Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX); Fast Auroral Snapshot (FAST); Transport Region and Coronal Explorer (TRACE); and Submillimeter Wave Astronomy Satellite (SWAS) missions, and the Multi-satellite Operations Control Center (MSOCC) which supports the Compton Gamma Ray Observatory (CGRO), Upper Atmosphere Research Satellite (UARS), Extreme Ultraviolet Explorer (EUVE), and Earth Radiation Budget Satellite (ERBS) missions. The Advanced Composition Explorer (ACE) and Tropical Rainfall Measurement Mission (TRMM) are also operated out of GSFC MOC's. Data processing support is provided for the ISTP/Geomagnetic Tail (Geotail) and Extreme Ultraviolet Explorer (EUVE) missions.

The CGRO has phased into the TPOCC architecture of distributed workstations first used for the International Monitoring Platform (IMP-8) mission. NASA's SAMPEX, FAST, and Submillimeter Wave Astronomy Satellite (SWAS) missions will be operated from a common control facility for Small Explorer missions. The SWAS Mission Operations Center has been completed. The Wide Field Infrared Explorer (WIRE) control center has also been completed. These workstation systems will allow for increased mission control capability at reduced cost.

The first launch of a Medium-class Explorer (MIDEX) is currently scheduled for January 2000. Approximately one spacecraft per year will be launched, with potentially every other MIDEX mission operated from GSFC, dependent on successful Principal Investigator teaming arrangements. To minimize operations costs, plans for the MIDEX missions include consolidating the spacecraft operations, flight dynamics and science data processing all into a single multi-mission control center. Many of the functions will be automated using a commercial expert system product. The control center system will be used for spacecraft integration and test, thereby eliminating the need and cost of unique spacecraft manufacturers integration and test systems.

Other mission control systems include the Space Shuttle Payload Operations Control Center (POCC) Interface Facility and the Command Management System. The Space Shuttle POCC Interface Facility (SPIF) is being upgraded with a low-cost, PC-based front-end data system now operating in shadow mode. The SPIF provides a single interface to the Mission Control Center for use of spacecraft mission control facilities to access spacecraft deployed by the Space Shuttle. The Command Management System generates command sequences to be used by mission control centers. A User Planning System, currently being upgraded to a workstation-based environment compatible with the Network Control Center (NCC) configuration, is provided for scheduling communications with spacecraft supported by the Tracking and Data Relay Satellite System (TDRSS); and the Flight-to-Ground Interface Engineering Center provides flight software pre-flight and in-flight simulation and development support for GSFC flight systems. An Operations Support Center maintains status records of in-flight NASA systems.

The data processing function captures spacecraft data received on the ground, verifies the quantity and quality of the data and prepares data sets ready for scientific analysis. The data processing facilities perform the first order of processing of spacecraft data prior to its distribution to science operations centers and to individual instrument managers and research teams.

Data processing facilities include the Packet Data Processing (PACOR) facility, the Data Distribution Facility, and the Telemetry Processing Facility. The PACOR facility utilizes the international Consultative Committee for Space Data Systems data protocol to facilitate a standardized method of supporting multiple spacecraft. PACOR provides a cost-effective means of processing flight data from SAMPEX, EUVE, CGRO, SOHO, SWAS, RXTE, TRMM, and HST spacecraft missions. The transfer of EUVE to the University of California at Berkley in FY 1998 and the relocation of CGRO processing to the workstation-based PACOR II in FY 1998 resulted in the closure of the older PACOR I system.

The Data Distribution Facility (DDF) performs electronic and physical media distribution of NASA space flight data to the science community. The DDF has been a pioneer in the use of Compact Disk-Read Only Memory technology for the distribution of spacecraft data to a large number of NASA customers. Specialized data processing services are provided by the Telemetry Processing Facility for the ISTP missions (Wind, Polar, and Geotail). The Spacelab Data Processing Facility, located at the MSFC, processes data from Space Shuttle payloads. Specialized telemetry processing systems for NASA's Space Network are also provided under this program.

The Mission Control and Data Systems program provides for the operation, sustainment, and improvement of NASA's Flight Dynamics Facility (FDF). Funding for the FDF is used to: provide orbit and attitude determination for operating NASA space flight systems, including the Tracking and Data Relay Satellite (TDRS) and the Space Shuttle; develop high-level operations concepts for future space flight systems; modify existing FDF systems to accommodate future missions; develop mission-unique attitude software and simulator systems for specific flight systems; generate star catalogues for general use; and conduct special studies of future orbit and attitude flight and ground system applications. It is critical to continuously know the location of spacecraft so as to communicate with the system and to know the orientation of the spacecraft to assess spacecraft health and safety and to perform accurate scientific observations. The type and level of support required by spacecraft systems is dependent on the design of its on-board attitude and control systems, including its maneuver capabilities, and the level of position and pointing accuracy required of the spacecraft. Automated orbit determination systems for TDRS and other spacecraft systems are also under development.

Besides the operation of currently deployed spacecraft and the modification and development of mission control and data processing systems to accommodate new flight systems, the program also supports the study of future flight missions and ground system approaches. Mission control and first-order data processing systems are less costly systems. Yet, proper economy of mission planning requires solutions that integrate ground and flight system development considerations. Special emphasis is given by the Mission Control and Data Systems program to seeking integrated solutions to spacecraft and ground systems designs that emphasize spacecraft autonomy; higher data transmission and processing rates; ease and low cost of operation; reuse of software; and selected use of advanced hardware and software design techniques to increase the return of space flight system investments at equal or lower cost than is required to support today's mission systems.

The Mission Control and Data Systems program supports advanced technology development at GSFC, JPL and GRC. The GSFC team, including contractors and universities, provides advanced technology in several area such as tracking and data acquisition future systems, communications and telemetry transport, and advanced space systems for users. Anticipating a future mission set characterized by large numbers of rapid, low-cost missions, the JPL team invests in technologies which can increase the overall capacity-to-cost ratio for the Deep Space Network. Efforts are focused on core technologies unique to, and critical for, deep space telecommunications, tracking and navigation, and radio science. Current technology areas include antenna systems, low noise systems, frequency and timing, radio metric tracking, navigation, network automation, atmospheric propagation and optical communications. The Glenn Research Center team identifies, develops, and demonstrates advanced radio frequency antennas, amplifiers, receivers, digital communications and hybrid network technologies and services for use in NASA missions and commercial systems.

The Mission Communication Services advanced technology development has three forms that include near term (1-3 years) demonstration and application of data management and telecommunications technology and procedures, mid-range (3-5 years) development of ground and space flight communications systems; and a long-term, pre-competitive technology development and demonstration make up. Consideration of innovative applications of commercial "off-the-shelf" (COTS) technology is emphasized. Such applications often open new market opportunities to suppliers of these technologies resulting from their NASA experience. Additionally, in response to White House National Space Policy, NASA is planning to transition its communications operations to commercial services. Technology developments and demonstrations focus on technology and service gaps to enable utilization of commercially provided services.

A critical element of the Mission Control and Data Systems program is the securing of adequate frequency spectrum resources which are required in the performance of all flight missions, piloted and unpiloted, including spectrum for all active emitters as well as passive sensors. GRC, in concert with NASA Headquarters Office of Space Flight, manages these resources for the Agency and coordinates frequency spectrum requirements with other federal agencies, industry and regulatory bodies to obtain all requisite authorizations to operate telecommunications systems associated with NASA programs. Consistent with its charter pursuant to both the Space Act of 1958 and the Communications Satellite Act of 1962, NASA also serves as an advocate for obtaining the unique frequency spectrum allocations required by the commercial sector to exploit satellite technology for future generation telecommunications systems. In compliance with the 1992 Telecommunications Authorization Act, NASA actively participates in the Interdepartment Radio Advisory Committee to establish National and International spectrum management policies.

SCHEDULE AND OUTPUTS

	FY 1998 Plan	FY 1998 Actual	FY 1999 Plan	FY 1999 Current	FY 2000 Plan
Number of NASA spacecraft supported by GSFC mission control facilities	19	17	16	22	23
Number of mission control hours of service (thousands)	56,000	56,000	40,000	66,000	67,000
Number of billions of bits of data processed	31,400	56,000	60,900	64,500	67,000
Number of NASA/Other missions provided flight dynamics services	41	37	30	44	49
Number of NASA/Other ELV launches supported by flight dynamics services	34	34	34	34	22

The FY 1998 actual mission control and data processing support reflects the TRMM and TRACE launches. Planned support for fiscal years 1999 and 2000 reflect Landsat-7 and EOS AM-1 launches. The number of missions provided flight dynamics services reflects the current mission model and includes pre-Phase A support for missions such as Earth Orbiter (EO)-1, Venus 2000, and Next Generation Space Telescope.

ACCOMPLISHMENTS AND PLANS

The Mission Control and Data Processing program has pursued proactive measures to consolidate functions, close marginal facilities, and reduce overall contractor workforce to reflect the Agency's goals. Examples include the transition of the EUVE MOC operations to TPOCC workstation systems and the outsourcing of these operations to the University of California at Berkeley (UCB), the completion of SAMPEX science transition to PACOR II, the in-process CGRO transition to TPOCC and PACOR II systems, and the use of automation to monitor routine spacecraft health and safety functions to enable smaller flight operations teams and reduced operations schedules.

Mission control was performed for the HST, CGRO, UARS, EUVE, SAMPEX, FAST, TRACE, SWAS, ICE, IMP-8, ERBS, TOMS-EP, RXTE, ISTP WIND, POLAR, SOHO, and ACE.

Packet data processing operations were provided for the HST, CGRO, EUVE, SAMPEX, FAST, SOHO, TOMS-EP, and RXTE, while TRACE received limited support. The Time Division Multiplexed services were provided for the Geomagnetic Tail, UARS, ERBS, ICE, IMP-8, POLAR, and WIND. Data processing for the Spacelab missions was performed at MSFC. Efforts were continued during FY 1998 on the ISTP Wind, Polar, SOHO and Geotail reengineering initiative to consolidate systems and operations around a greater use of commercial products to substantially reduce recurring costs aimed at extending mission life beyond FY 1998.

Flight dynamics services were provided to all NASA space flight missions that utilize NASA's Space Network and to selected elements of the Ground Network, including the Space Shuttle, Expendable Launch Vehicles, and satellite systems. A new operations concept for flight dynamics was developed. The new concept defines an approach to reduce flight dynamics costs by implementing new technology. Attitude software and simulator development was provided for the TRACE, ACE, and TRMM flight systems.

Among systems implementation projects, development of TPOCC systems for the TRMM and ACE spacecraft was completed, including the procurement of workstations, processors, and software. Modifications of the Command Management System effecting workstation deployment to specific MOC's were completed, with CGRO the only residual mission operating on a reduced configuration IBM mainframe. TPOCC development for the EUVE missions was completed and the transition for CGRO continued. The development of innovative spacecraft integration and test and mission operation single system ground support development efforts for the MIDEX Microwave Anisotropy Probe (MAP) and MIDEX Imager for Magnetopause to Aurora Global Exploration (IMAGE), and the Small-class Explorer (SMEX) WIRE MOC's will be continued. The Integrated Test and Operations System (ITOS) was implemented for the SMEX TRACE mission and was utilized for launch and early orbit support and now for routine operations.

The spacecraft managed by GSFC's mission control facilities are supported by various NASA communications networks, including the TDRSS, the DSN, the WFF, and transportable ground systems. A wide range of communications and systems interfaces must be managed to accomplish the function of mission control. NASA mission operations personnel support the planning and development of future mission systems and continuous changes to operational spacecraft software systems, as well as the operation of current ground control systems.

Transfer of data systems technologies to flight project use occurred in the areas of software reuse, Very Large Scale Integration (VLSI) applications, expert system monitoring of spacecraft control functions, and packet data processing systems. Software reuse, expert systems, VLSI user interface, workstation environments, and object-oriented language applications continued. The Mission Control and Data Systems programs will continue to integrate modern technology into mission operations support systems through the use of systems like the Generic Spacecraft Analyst Assistant (GenSAA) for automation, software-based telemetry front-end processing systems and the Mission Operations Planning and Scheduling System, case-based and model-based reasoning tools, and commercial orbit planning systems.

In support of Advanced Technology Development, planning and implementation continued on demonstrating optical laser communications between the ground and an Earth-orbiting spacecraft using the JPL ground facilities and the Japanese ETS-VI satellite. A contract was placed for a 4th-generation, lightweight, low-power-consuming radio transponder for users of the TDRSS.

Conversion of CGRO to TPOCC and PACOR II systems was completed in FY 1998. The ISTP reengineering systems for mission control and science processing will begin phase-over to operations in FY 1999. MOC development for WIRE has been completed. MOC development for Landsat-7 will be completed, incorporating a commercial state modeling tool to help automate operations. RXTE and CGRO operations have incorporated GenSAA and other automation tools to promote reduced shift staffing. Attitude software and simulator development is being provided for the TRACE, WIRE, and TRMM flight systems. The TRMM and TRACE missions will be supported by GSFC's data processing program. The SAMPEX flight dynamics operations support will finalize its transition from the Flight Dynamics Facility at GSFC to the University of Maryland's Flight Dynamics Control Lab in FY 1999. Flight dynamics ground systems will be provided for EOS AM-1, EOS PM-1, and LANDSAT-7.

Reimbursable support will be provided to multiple missions, including Geostationary Operational Environmental Satellite (GOES) and National Oceanic Atmospheric Administration (NOAA) programs. Mission planning for future missions such as HST Servicing Missions, Next Generation Space Telescope, EO-2 and EOS will be performed.

Advanced technology initiatives will continue. The 4th generation TDRSS radio transponder engineering unit is underway. Work on deep space radio transponders and data coding technology continues.

Mission Control and Data Systems provided Mission Control, Flight Dynamics and Data Processing service for the TRMM and TRACE missions launched in FY 1998; similar support will be provided to the Landsat-7 mission scheduled to be launched in FY 1999. Significant development, test, and pre-launch support associated with the MIDEX and SMEX missions are part of the Mission Control and Data Systems activity.

Emphasis upon commercial products, artificial intelligence applications and advanced graphical displays will be continued in FY 1999 for application in MIDEX and future SMEX missions. Evolution of systems to a single integrated mission control, command management, flight dynamics, and first-level science processing system will continue. A new Flight Dynamics Facility (FDF) operations concept to perform routine operations as integral functions within mission control centers will be fully implemented in FY 1999. New flight dynamics technology development for autonomous space and/or ground spacecraft navigation and control will be major efforts.

Preparations for the HST Third Servicing Mission will continue, including the delivery of the Vision 2000 ground system, delivery of the new flight control computer flight software, and the payload computer ACS support system. Development efforts will take place in preparation for TRACE, SWAS, WIRE, and MIDEX missions.

The Mission Operations and Data Systems program will focus efforts at operations automation. Mission Control and Data Systems will complete development efforts on the RXTE Automated POCC (APOCC) and the CGRO Reduced Operations by Optimizing Tasks and Technologies (ROBOTT) efforts. Automation was provided for TRACE to promote single shift staffing for operations. Mission Control and Data Systems will actively lead and participate in establishing new architecture directions and rapid prototyping, exploring system autonomy concepts, and use of commercial-off-the-shelf products.

Mission Control and Data Systems program will continue the lead in scoping and prototyping Mission Operations Control Architecture (MOCA) elements such as the use of Transmission Control Protocol/Internet Protocol or Space Communications Protocol Standards for ground and flight communications, the use of knowledge-based control languages, ground and space autonomy; and active participation in the American Institute of Aeronautics and Astronautics Spacecraft Control Working Group to infuse emerging operations standards in the areas of satellite control. Exploration of the promise of advanced communications technologies will continue throughout this period.

WIRE, SWAS, IMAGE, and HST SM3 development will be completed in FY 1999. Developments will continue for the MIDEX and SMEX series as well as for the fourth HST Servicing Mission (HST SM4). Development efforts on WIRE, MAP, Imager for Magnetopause-to-Aurora Global Exploration (IMAGE), EO-1, and similar missions will realize benefits from modern technology, commercial products, and more cost-effective processes. A prime example would be a single system to perform spacecraft integration and test and mission operations. The flight dynamics work will continue to be provided in the areas of ground support system development, analysis, and automation tools. In the area of analysis, work will continue with advanced mission studies needed for pre-phase A efforts, while Phases C and D work will be done to support various EOS, MIDEX, and SMEX missions. The ground systems for those missions will also be developed. Automation efforts will continue in an effort to reduce costs and increase the capability of spacecraft. This will include such items as onboard maneuver planning and station keeping that permits such mission scenarios as formation flying. Additional work will be completed in the area of mission planning tool development that will be in partnership with industry. Throughout all of these efforts, continual process improvement in the areas of analysis and software development will continue to occur with a view toward reducing costs and cycle time and improving quality.

The Advanced Communications Technology Satellite (ACTS) has completed its period of normal station kept operation and commenced a period of extended life operation in an inclined, fuel saving orbit in FY 1998. Reversion to this mode of operation extends its life by 2 additional years. Continued use of the satellite through FY2000 requires the use of tracking earth terminals. The system continues to contribute to NASA's transition to commercial services by its use as a testbed for resolving technical issues.

A GRC experiment to demonstrate the feasibility of using commercially provided Direct Data Distribution (D3) services from low earth orbiting NASA and commercial spacecraft was initiated in FY 1998 and is now in the concept development phase. A detailed experiment plan was developed to demonstrate the D3 concept using a K-Band phased array antenna (under cooperative development with Raytheon), multi-channel broadband modems (leveraging a 155-Mbps modem chip set developed with SICOM), and compact commercial ground-based tracking terminals. Plans to manifest the space segment of the experiment on the Space Transportation System using the GSFC Hitchhiker carrier system are in process. The ground segment will be located to communicate with the STS and interface with terrestrial telecommunications networks. Plans are being developed for insertion of the commercial D3 capability into International Space Station communications upgrades, near-Earth science spacecraft, and next-generation LEO satellite systems.

During FY 1998 and FY 1999 GRC evaluated industry responses to a CBD announcement requesting information on the suitability of planned commercial systems to meet NASA communications needs in near-Earth orbits. Preliminary results emphasized the need for focused technology development in order for NASA missions such as ISS to use the commercial systems with some modifications. Planning will be initiated in FY 1999 to collaborate with suitable commercial partners on technologies to enable a commercial Space Internet Architecture and NASA' us use of the commercial communications and operation services it will provide. The commercial Space Internet will enable spacecraft instruments to be accessed by principle investigators directly as a node on the Internet. A first generation commercial network transponder and associated inter-orbital intersatellite link components will enable near-Earth spacecraft to communicate directly with selected commercial non-GEO and GEO satellites. Development of a space communications and networks testbed on ISS will allow rapid demonstration of emerging technologies and augmentation of ISS data transmission capabilities. In FY 2000, GRC will extend its efforts to understand the signal propagation characteristics to millimeter wave frequencies (Ka-band and above) in support of long-term, pre-competitive technology development.

In FY 1999 GRC will initiate the development of Ka-band traveling wave tube (TWT) breadboard leading to TWT amplifiers (TWTA) for use in deep space missions that will return science data via the upgraded Deep Space Network. In FY 2001 the engineering model TWTA will be completed and the first of several flight model TWTAs will be initiated jointly with JPL.

In FY 1998 the vehicle for NASA/DoD/Industry collaboration on development of pre-competitive technologies and service enabling demonstrations of mutual benefit to all, transitioned from the NASA-led Satellite Alliance USA to the DoD-led Space Technology Alliance. The Office of Chief Technologist will facilitate future collaborative efforts by NASA.

During FY 1998, the NASA Spectrum Management Program participated in the US Delegation to the 1997 World Radio-communications Conference (WRC-97) and contributed to the significant success achieved in the area of space science related proposals. NASA also provided critical support to US efforts at WRC-97 aimed at defending the radio navigation satellite service spectrum used by the Global Positioning System (GPS). Study efforts were begun that focused on sharing issues in preparation for WRC-2000 and beyond. Proposals were developed regarding passive microwave sensor bands above 70 GHz. Significant activities were carried out, nationally and internationally, to support the use of GPS for space navigation and to secure the necessary regulatory protection of such use. Efforts were begun to identify spectrum needed to support broadband aeronautical telemetry requirements and coordination of these requirements within Government and industry. NASA continued to seek means to maximally utilize the limited and valuable orbit spectrum resources it needs to carry out its missions.

In FY 1999, the Spectrum Management Program will develop and advocate the Agency proposals for WRC-2000. Study efforts laying the groundwork for these proposals will be completed and recommendations formulated within the relevant International Telecommunications Union study groups and working parties. NASA will also continue efforts toward improving the regulatory status for frequency bands that are vital to carrying out the Agency's missions. NASA will continue to support US efforts at maintaining an interference free environment for the Global Positioning System and to garner support from the World's space agencies for space-based radio navigation. NASA will prepare for the WRC-2000 Conference Preparatory Meeting (CPM 99-2) scheduled for the fall of 1999.

In FY 2000, the Spectrum Management Program will participate in the conference Preparatory Meeting (CPM 99-2) to ensure that the technical bases needed to support US/NASA proposals at WRC-2000 is reflected in the CPM Report to the Conference. NASA will finalize proposals for WRC-2000 and participate in the US preparatory process. NASA will serve on the US Delegation to WRC-2000, providing leadership on space science issues and providing support to other issues of concern to NASA and the US such as GPS.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE NETWORK CUSTOMER SERVICES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Space Network Customer Services	31,100	25,700	27,000

PROGRAM GOALS

The goal of the Space Network Customer Service program is to provide high quality, reliable, cost-effective customer access to the multi-mission space telecommunications network serving all TDRS-compatible Earth orbiting and suborbital flight missions and to provide network control and scheduling services to customers of both the Space Network and selected Ground Networks elements.

STRATEGY FOR ACHIEVING GOALS

This program develops and maintains both the management and technical interfaces for customers for the Space Network. The Network Control Center (NCC), located at the Goddard Space Flight Center in Maryland, is the primary interface for all customer missions. The primary function of the NCC is to provide scheduling for customer mission services. In addition the NCC generates and transmits configuration control messages to the network's ground terminals and TDRS satellites and provides fault isolation services for the network. The Customer Services program also provides comprehensive mission planning, user communications systems analysis, mission analysis, network loading analysis, and other customer services and tests to insure network readiness and technical compatibility for in-flight communications.

The Lockheed Martin Space Operations Company was recently awarded the Consolidated Space Operations Contract (CSOC) and will be the primary contractor responsible for systems engineering, software development and maintenance, operations, and analytical services beginning in January 1999.

The Customer Services program also undertakes network adaptations to meet specific user needs and provides assistance to test and demonstrate emerging technologies and communications techniques. A low power, portable transmit/receive terminal, called Portcom, which operates with TDRS spacecraft has been demonstrated. Potential applications include data collection from remote sites where commercial capabilities do not exist, such as NOAA ocean research buoys and National Science Foundation (NSF) Antarctic activities. A series of tests are being conducted with Japanese and European satellites and data acquisition communications systems for mutual provision of emergency operational spacecraft support.

SCHEDULE AND OUTPUTS

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Current	Plan
Number of NASA spacecraft events supported by the NCC	80,900	76,000	98,000	99,900	100,800

The number of NASA Spacecraft events supported by the NCC increased in FY 1998 with the TRMM and ETX-VII missions and will increase further with the FY 1999 additions of Landsat-7, EOS AM-1, and the International Space Station (ISS) assembly activities. The FY 2000 increase is due to the anticipated full-up support of the ISS mission.

ACCOMPLISHMENTS AND PLANS

Implementation was continued on an improved, distributed architecture for the NCC which will be Year 2000 (Y2K) compliant. When completed, this modification will provide more efficient use of the network capabilities, improved ability to resolve scheduling conflicts among customer missions, and provide standard commercial protocols for both internal and customer interfaces. This architectural change will be undertaken over several years and accomplished segment by segment. The segment of the control center to be modified first is the service scheduling system.

The NCC modifications to the scheduling system continued including incorporation of standard commercial protocols and the Request Oriented Scheduling Engine (ROSE) which provides special features for conflict-free spacecraft scheduling such as goal-directed scheduling and repetitive activities with variable start times and durations. The development of a compact transponder, using new technology, suitable for use by new, small satellites was continued. This dual award procurement will provide engineering models and a small number of flight units from both Cincinnati Electronics and Motorola. These small satellite transponders expand Space Network/TDRS use to a new class of missions. A contract was initiated to design and develop a Ka-Band Phased Array Antenna. This system will enable Low Earth Orbiting (LEO) spacecraft to establish high data rate communications in the Ka frequency band, either to ground stations or via TDRSS-H, I, J.

The Space Network Customer Services program will provide for continued operations, maintenance, and modification of the NCC. The scheduling system modification will be completed and become operational. The communication and control segment modification effort will be initiated. This segment modification will complete the distributed architecture modifications and lower the life cycle cost of the Network Control Center.

The Service Planning Segment Replacement project will become operational in FY 1999 in the Space Network Control Center (NCC). This will start the implementation of the Network Control Center Data System into a workstation, Unix-based environment, resulting in an estimated 40 percent reduction in life cycle costs. Development of a fourth generation TDRS spacecraft communications system for use by small satellites will near completion while development efforts for the Ka-Band Phased Array Antenna will continue.

The requested funding also provides for continuation of mission planning, customer requirements definition and documentation, mission and network operational analyses, customer communications systems analyses, test coordination and conduct, and other customer support services. An interoperability demonstration with the TRMM spacecraft was conducted in FY 1998. Compatibility testing is planned for Landsat-7, EOS AM-1, International Space Station, WIRE, and upcoming National Oceanic and Atmospheric Administration (NOAA) missions in FY 1999. Simulations, engineering tests, and data flows will be conducted to verify communications designs and train mission control operators.

The Space Network Customer Services program will provide for continued operations, maintenance, and modification of the NCC. The Communications and Control Segment Replacement project will begin in the Space Network Control Center (NCC) in FY 1999 and will allow the completion of the implementation of the Network Control Center Data System into a workstation, Unix-based environment, resulting in an estimated 50 percent reduction in the amount of application code and a reduction in life-cycle cost. The fourth generation TDRS transponder will be available in FY 1999 and development efforts on the Ka-Band Phased Array Antenna will near completion.

In FY 2000, the Communications and Control Segment Replacement project in the Space Network Control Center (NCC) will become operational. The Ka-Band Phased Array Antenna will be completed. Also in this timeframe, the CSOC contractor, Lockheed Martin Space Operations Company, will be implementing architectural changes to reduce operations costs. One current area of consideration is consolidation of the NCC functions for the Space Network with scheduling functions for the Deep Space Network and Ground Network at a central location. These plans will be reviewed by the government as they are formulated.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998	FY 1999	FY 2000	Page Number
	(Thousands of Dollars)			
Education	76,800	71,600	54,100	SAT 6.1-1
Minority research and education	53,200	66,900	45,900	SAT 6.2-1
Total	130,000	138,500	100,000	

SCIENCE AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS **EDUCATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
		(Thousands of Dollars)		
Student support programs	8,900	8,600	8,600	SAT 6.1-7
Teacher/faculty preparation and enhancement programs	12,900	12,800	12,800	SAT 6.1-9
Support for systemic improvement of education	29,900	35,300	24,300	SAT 6.1-12
Educational technology	24,400	14,200	7,700	SAT 6.1-16
Evaluation	700	700	700	SAT 6.1-19
Total	76,800	71,600	54,100	

Distribution of Program Amount by Installation

	FY 1998	FY 1999	FY 2000
Johnson Space Center	1,100	1,300	1,300
Kennedy Space Center	600	800	800
Marshall Space Flight Center	2,200	2,800	2,800
Stennis Space Center	500	900	900
Ames Research Center	6,700	3,900	3,900
Langley Research Center	1,200	1,200	1,200
Glenn Research Center	1,000	1,100	1,100
Dryden Flight Research Center	200	500	500
Goddard Space Flight Center	52,200	48,300	30,800
Jet Propulsion Laboratory	1,500	1,400	1,400
Headquarters	9,600	9,400	9,400
Total	76,800	71,600	54,100

PROGRAM GOALS

NASA's direction for education is set forth in the NASA Strategic Plan as one of the Agency's five contributions to the Nation's science and technology goals and priorities:

> ***Educational Excellence.*** *We involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds.*

This contribution is accomplished through implementation of a full range of NASA education programs and activities that contribute to the various efforts and activities of those involved with and in the education community, and benefit the participants as well as advance the mission of the Agency. Progress towards this goal is measured in two ways:

- **Excellence**: NASA seeks to be judged by its customer, the education community, as providing excellent and valuable educational programs and services. Therefore we will attempt to maintain an "Excellence" rating ranging between 4.3 and 5.0 (on a 5.0 scale) as rated by our customers.
- **Involvement**: NASA strives to involve the educational community in our endeavors. Therefore, at the proposed funding level, we seek to maintain a current level of participant involvement of approximately 3 million with the education community, including teachers, faculty, and students.

STRATEGY FOR ACHIEVING GOALS

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the NASA mission holds for students and educators. The unique character of NASA's exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into education endeavors which support local, state, and national educational priorities.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with NASA's scientists and engineers, facilities, and research and development activities.

The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of NASA's activities, and return to the classroom with enhanced knowledge and skills to share with the education community. NASA contributes to promoting excellence in education by providing access to and involvement in the NASA mission. Underpinning the entire Education Program is the commitment to involve participants from diverse and underrepresented populations in the science, mathematics and technology pipeline.

NASA Implementation Plan for Education

The NASA Implementation Plan for Education, one component of the NASA Strategic Management System, provides general guidance for the implementation and continual improvement of the NASA Education Program for fiscal years 1999-2003. Specifically, the plan

- Identifies three leadership strategies to improve and guide the NASA Education Program: (1) contribute to educational excellence; (2) develop alliances; and (3) involve the education community.
- Outlines the education agenda for the next five years through seven improvement initiatives: (1) focus and coordinate state-based efforts; (2) enhance instructional products and dissemination; (3) improve education program integration and coordination; (4) facilitate NASA research in the higher education community; (5) support pre-service education; (6) target informal education; and (7) implement NASA's comprehensive data collection and evaluation system.
- Delineates the operating principles integral to the conduct of all NASA education activities: customer focus; collaboration; diversity; and evaluation.
- Defines the NASA Education Program and Evaluation Framework, the basis from which our agency-wide and center-based programs are organized, implemented, and evaluated.
- Describes the roles and responsibilities of the various organizational entities that carry out the NASA Education Program.

This plan provides guidance for agency-wide education programs as well as programs and activities carried out by the NASA Enterprise Offices, the Office of Equal Opportunity Programs, and the NASA field centers.

SCHEDULES & OUTPUTS

The NASA Education Program and Evaluation Framework was established to serve as a model to guide the implementation and evaluation of NASA's Education Program. The framework was first proposed based on a study conducted by a panel of distinguished experts in education and evaluation. The National Research Council convened this panel in 1994 and produced the report, *NASA's Education Programs: Defining Goals, Assessing Outcomes*, which provided general guidance to NASA on establishing program goals and evaluation indicators. On November 30, 1994, the proposed framework was presented to NASA education personnel, including Center Education Directors, the Director of Minority University Research and Education Programs, the Center University Affairs Officers, the Center Pre-College Officers, and the Center Equal Employment Opportunity Officers at a meeting held at the NASA Johnson Space Center. This meeting resulted in Agency-wide consensus on the framework and the establishment of goals for each implementation approach. From that time until now, the framework has been refined and updated, reflecting direction defined in the NASA Strategic Plan.

This framework integrates NASA's Education Program, which touches the entire range of the education "customer" community, with the programmatic activities of NASA's Enterprises. Each category identifies a goal that reflects its role in relationship to the NASA mission, and is supported by performance measures for evaluation. These categories are:

- Student Support

  Goal: To use the NASA mission, facilities, human resources. and programs to provide information, experiences, and research opportunities for students at all levels to support the enhancement of knowledge and skills in the areas of science, mathematics. technology, and geography.

- Teacher/Faculty Preparation and Enhancement

  Goal: To use the NASA mission, facilities, human resources, and programs to provide exposure and experiences to educators and faculty to support the enhancement of knowledge and skills, and to provide access to NASA information in science, mathematics, technology, and geography.

- Support for Systemic Improvement of Education

  Goal: To use NASA's unique assets to support local, state, regional, and national science, mathematics. technology, engineering, and geography education change efforts through collaboration with internal and external stakeholders.

- Curriculum Support and Dissemination

  Goal: To develop, utilize, and disseminate science, mathematics, technology, and geography instructional materials based on NASA's unique mission and results, and to support the development of higher education curricula.

- Educational Technology

  Goal: To research and develop products and services that facilitate the application of technology to enhance the educational process for formal and informal education and lifelong learning.

- Research and Development

  Goal: To involve the education community, particularly higher education, in NASA programs that contribute to the development of new knowledge in support of the NASA mission, and to utilize the talent and resources of the higher education community.

During FY 1998. NASA has further refined and implemented the framework and the evaluation system that was pilot tested in FY 1996. Three levels of performance measures liave been developed. At the top level, all programs have measures that relate to the Program's primary metrics: excellence and involvement. Data showing progress towards these metrics are provided below. At the second level, each implementation approach has specific measures that all programs in that particular category are measured against such as career goals, program value, curriculum integration/use, standards awareness and utilization, overall quality, partnerships/alliances, service quality, and usage. At the third level, each program, in addition to the applicable second level measures, has program specific measures that show progress as well as participant written feedback that provides qualitative evaluation data.

Progress Towards Metrics

In FY 1998, the NASA evaluation system was able to collect data on most of the Agency wide education programs, and many center-specific programs and activities. The data summary below is a roll up of top-level measures that relate to the Education Program's two metrics -- excellence and involvement. The data is for FY 1998, as of 11/18/98. This is still considered preliminary as data roll up continues until January 1999.

- **Excellence**: NASA seeks to be judged by its customer, the education community, as providing excellent and valuable educational programs and services. Therefore we will attempt to maintain an "Excellence" rating ranging between 4.3 and 5.0 (on a 5.0 scale) as rated by our customers.

Progress towards this metric is measured by a quality rating by the educational customer of NASA's performance. The following data were collected:

Participant ratings of excellence (score: 5=excellent to 1=very poor; total participants reporting: 2,200)
- 4.70 Recommend to others
- 4.59 Rate staff
- 4.59 Expect to apply what was learned
- 4.73 Valuable experience
- Overall average for excellence: 4.65

Based on this information, the NASA Education Program is meeting its metric of excellence, as defined by the satisfaction expressed by our customers. As the FY 1998 data collection is completed, it is anticipated that additional participants will report, but we do not expect the ratings to change significantly.

- **Involvement**: NASA strives to involve the educational community in our endeavors. Therefore, at the proposed funding level, we seek to maintain a level of participant involvement of approximately 3 million with the education community, including teachers, faculty, and students.

Progress towards this metric is measured in three ways: (1) total number of students/teachers/faculty involved in NASA education programs; (2) number of partnerships/collaborations; and (3) number of programs using NASA assets and types of assets used. The following data were collected:

Total involvement in NASA Education activities: 21,843,242 (151 programs reporting)

- In person: 3,108,258; electronic: 6,431,900; general public: 13,393,084
- 93% students; 6% teachers/faculty; 1% other
- Students: 2,293,018; 51% K-4; 24% 5-8; 23% 9-12; 2% undergraduate; 0.4% grad
- Educators/faculty: 140,355; 23% K-4; 40% 5-8; 28% 9-12; 1% community college; 2% undergraduate; 6% graduate

Types of K-12 schools represented (2,664 participants reporting)

- 39% urban; 37% suburban; 24% rural

Partnerships/collaborations

- higher education institutions; industry; contractors; other NASA facilities; Educator Resource Center Network; non-profits; local community; school districts

Programs using NASA facilities

- 120 (note, some programs use multiple facilities): aircraft-28; ground trainers-14; laboratories-68; wind tunnels-20; VITS-video-19; computer labs-53; mockup facilities-24; auditoriums-48; classrooms-55

It is clear from the numbers above that the NASA Education Program is meeting the metric of involving 3 million students and educators in our programs and we anticipate continuing to do so in FY 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

STUDENT SUPPORT PROGRAMS

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Elementary and secondary	2,100	2,200	2,200
Higher education	8,900	6,400	6,400
Total	8,900	8,600	8,600

PROGRAM GOALS

The goal of the Student Support Program is to use the NASA mission, facilities. human resources, and programs to provide information, experiences, and research opportunities for students at all levels to support the enhancement of knowledge and skills in the areas of science, mathematics, engineering, and technology.

STRATEGY FOR ACHIEVING GOALS

Student support activities (1) provide NASA mission experiences and information that are designed to promote students' interest and achievement in science, mathematics, technology, and geography; (2) provide exposure to NASA research and/or research experiences and activities to promote science, mathematics, technology, engineering, and geography career awareness; **(3)** provide support to the science and technology workforce pipeline by including greater participation of individuals who are underrepresented in science, mathematics, technology, and geography in NASA student programs; and (4) increase the number of NASA student support opportunities through partnerships and interagency cooperation and collaboration.

Activities such as the NASA Student Involvement Program (NSIP) and the Shuttle Amateur Radio Experiment (SAREX) provide general exposure to NASA's mission and stimulate interest in mathematics, science, and technology subject matter. Additional activities such as the Summer High School Apprenticeship Research Program (SHARP and SHARP-PLUS), demonstrate the applications of mathematics, science and technology by providing research experiences for students who traditionally have not been represented in mathematics, science and engineering fields. At the higher education level. activities such as the Graduate Student Researchers Program (GSRP) provide support to train students in NASA-related disciplines at both the master's and doctoral levels.

SCHEDULE & OUTPUTS

As reported above, in FY 98, 2,293,018 students participated in **NASA** education activities. Elementary/secondary students comprised almost 98% of that number, in a variety of programs, projects, and activities.

In addition to collecting "excellence" and "involvement" data, second level metrics are also collected for student support programs. These include data on applicant/award ratio; gender, ethnicity, demographics; college major; career goals; interest change; and program value.

For example, 447 students participated in the Summer High School Apprentice Research Program (SHARP/SHARP Plus). This program involves underrepresented minority high school students in intensive research apprenticeships with NASA, industry, and university scientists and engineers. SHARP students live within commuting distance of a NASA installation; SHARP PLUS students have residential research experiences at a participating Historically Black College or University or a Predominately Minority Institution. The goal of both programs is to involve students from groups traditionally underrepresented in science, mathematics, engineering, and technology in a research environment. The program is very competitive as only 23% of those who apply are accepted into the program. Seventy four percent of these students are juniors in high school when they enter the program; 52% of the participants are female; approximately 30% are African American and 14% are Hispanic. Participants rate the program as being a valuable experience (4.75) and would recommend to others (4.65) (Score: 5=excellent; 1=very poor). At the conclusion of their experience, 47% indicated a career goal being an engineer (level of interest in this discipline area changed for a 3.2 to 4.2 over the course of the experience).

ACCOMPLISHMENTS AND PLANS

General plans for Student Support Programs in FY 1999 and FY 2000 include the development and maintenance of electronically disseminated communication of NASA-sponsored student opportunities and career information to our customers, and better coordination of student program efforts across the NASA system to ensure the progression of students from one program to another.

FY 1998 accomplishments for SHARP/SHARP Plus are cited above. In FY 1999, the two programs will be combined under one procurement vehicle, which will create greater efficiencies in the management of these programs. However, both the residential and center based components will be maintained.

Other agency-wide student programs include the NASA Student Involvement Program, Shuttle Amateur Radio Experiment, and the Graduate Student Researchers Program. In FY 1998 the Space Science Student Involvement Program was redesigned and renamed the NASA Student Involvement Program (NSIP). The program continues to promote literacy in science, mathematics, and technology among students in grades 3-12. More than 10,000 students continued to participate in the program. The redesigned program will insure closer linkages with the NASA Enterprises and provide standards-based, hands-on, inquiry-oriented learning experiences. In FY 1999, the redesigned program will be fully operational.

The Shuttle Amateur Radio Experiment continued in FY 1998 to provide students the opportunity to participate directly in the Shuttle program by communicating directly with astronauts via amateur radio. Again, more than 10,000 students participated in this overall program and SAREX was flown on 2 Shuttle missions with 17 schools and 2,850 students talking directly with astronauts on those missions. In FY 1999, work will continue to integrate SAREX on the International Space Station.

The Graduate Student Researchers Program continued in FY 1998 to provide graduate fellowships to U.S. citizens conducting thesis research in NASA related areas. Approximately 400 students were supported full time, and a similar number is expected in FY 1999. In FY 2000, Student Programs will be maintained at the same funding and participation levels as in FY 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

TEACHER/FACULTY PREPARATION AND ENHANCEMENT PROGRAMS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Elementary and secondary	4,700	4,200	4,200
Higher education	8,200	8,600	8,600
Total	12,900	12,800	12,800

PROGRAM GOALS

The goal of the Teacher/Faculty Preparation and Enhancement Programs is to use the NASA mission, facilities, human resources, and programs to provide exposure and experiences to educators and faculty, to support the enhancement of knowledge and skills, and to provide access to NASA information in science, mathematics, technology, engineering, and geography.

STRATEGY FOR ACHIEVING GOALS

At the elementary and secondary level, preparation and enhancement activities are designed to (1) provide NASA mission-based programs that introduce the application of science, mathematics, geography, engineering, and technology for use in student learning activities; (2) provide educators with a wider range of alternatives using scientific inquiry, based on the NASA mission; (3) encourage a "multiplier" effect to expand the benefits of the inservice program beyond participants to include additional educators; (4) provide access to and promote utilization of NASA related materials and information resources; (5) increase the participation of underserved and underutilized individuals and groups; and (6) facilitate collaborations between the faculty of teacher preparation departments and the faculty of scientific and technical departments to develop innovative approaches to teacher preparation. Pre-service programs such as Project NOVA, and in-service programs such as the NASA Education Workshops (NEW) and the Urban Community Enrichment Program (UCEP) are designed to enhance and improve the teaching of mathematics, science, and technology by demonstrating their applications in aeronautics and space through workshops around the country. The Teaching From Space Program continues to provide instructional products that help support these preparation and enhancement workshops.

At the higher education level, activities are designed to enhance faculty research skills and content knowledge; balance participation so that a cross-section of colleges and universities is represented (i.e., community colleges, four year institutions, institutions that serve significant numbers of underrepresented groups, underfunded institutions); and provide opportunities for curriculum expansion/revision that aligns with the mission needs of NASA and universities. Activities such as the Summer Faculty Fellowship Program (SFFP) and the NASA/University Joint Venture (JOVE) Program provide research experiences for faculty at NASA field centers to further their professional knowledge in the engineering and science disciplines, and to ultimately enhance the undergraduate/graduate curriculum.

SCHEDULE & OUTPUTS

As reported earlier, in FY 1998, 140,355 educators and faculty participated in NASA education activities. K-12 educators comprised approximately 91% of that number.

In addition to collecting "excellence" and "involvement'" data, NASA collects second level metrics for these programs. These include data on applicant/award ratio; gender, ethnicity, demographics; program value; extramural funding; curricula integration/use; and standards awareness.

For example, 382 educators participated in the NASA Education Workshops (NEW). These workshops, held at NASA centers during the summer, provide an opportunity for practicing teachers to update their background and skills in science, mathematics, and technology. The program is competitive – 29% of applicants are accepted. Thirty-eight percent of participants represent suburban schools, 34% urban, and 28% rural. On a rating scale of 5 (5=excellent; 1=very poor), participants rated "expect to apply what learned" at 4.76 and "valuable experience" at 4.73.

ACCOMPLISHMENTS AND PLANS

General plans for teacher/faculty preparation/enhancement programs in FY 1999 and FY 2000 include plans to model inquiry-based science investigations or meaningful mathematics problem solving by engaging educators in the kinds of learning they are expected to practice with their students; expand follow-up and networking opportunities for the alumni of NASA's teacher enhancement programs; expand the scope of educator enhancement programs to include workshops at each center for institutions in their region that serve informal education and urban/rural systemic efforts; provide education experiences for educators in the effective application of educational technologies; and define and execute activities that target pre-service education programs.

FY 1998 accomplishments for NEW are cited above. In FY 1999, partnerships between NASA and rural and urban education systems will be strengthened through center based workshops. Other agency-wide programs include the following:

Teacher preparation programs such as Project NOVA disseminate nationally an undergraduate pre-service model based on standards and benchmarks for science, mathematics, and technology. NOVA links higher education faculty across several disciplines to create these models. To date, more than 100 colleges and universities have participated. The Urban Community Enrichment Program (UCEP) provides more than 750 urban teachers greater exposure to new NASA knowledge. In FY 1998, UCEP programs were conducted in Kansas, Oklahoma, Texas, Maryland, and Guam. The Teaching from Space Program continues to develop products that are incorporated into enhancement activities, providing tools that can be applied in the classroom and disseminated through the Educator Resource Center Network.

At the higher education level, the Summer Faculty Fellowship Program provides highly beneficial opportunities for U. S. citizen engineering and science faculty throughout the Nation to participate in NASA research. This program has contributed significantly to the improvement of both undergraduate and graduate education, and directly benefits NASA, universities, faculty, students and the Nation. Approximately 300 university faculty continues to be supported annually for ten weeks. This program is being combined with the Joint Venture (JOVE) Program, which also provides opportunities for college and university faculty to come to NASA centers to work with NASA data and to enhance research and teaching capabilities. There are currently approximately 100 academic institutions participating, most of who had little previous contact with the agency. It is NASA's intent to take the best of both programs -- center research opportunities of SFFP and follow-on opportunities of JOVE -- and create a new program that would begin in late FY 1999.

The impact of slightly reduced funding levels in FY 1999 will be evidenced by slightly lower participation rates in workshops or in a reduced number of workshop opportunities at both the pre-college and higher education levels. In FY 2000, Teacher/Faculty programs will be maintained at the same funding and participation levels as in FY 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

SUPPORT FOR SYSTEMIC IMPROVEMENT OF EDUCATION

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Aerospace Education Services Program (AESP).	5,600	5.600	5,600
National Space Grant College and Fellowship Program..	19,100	19,100	13.500
Experimental Program to Stimulate Competitive Research..	4,600	10,000	4,600
Innovative Reform Initiatives..	600	600	600
Total	29,900	35,300	24,300

PROGRAM GOALS

The goal of the Support for Systemic Improvement of Education Program is to use NASA's unique assets to support local, state, regional, and national science, mathematics, technology, engineering, and geography education change efforts through collaboration with internal and external stakeholders.

Systemic improvement encompasses the process whereby an entire system is re-engineered toward achieving a new goal. NASA is committed to supporting systemic initiatives in the areas of science and mathematics education, and its activities vary depending on the needs of the institution, school system, and/or state. Thus, the activities supported by programs included in this category seek to provide a range of support in response to the needs of the customer community.

STRATEGY FOR ACHIEVING GOALS

Systemic improvement activities are designed to: (1) coordinate planning among NASA education initiatives to ensure alignment with and support of standards-led systemic improvement initiatives of the states: (2)redirect existing education programs, and ensure new initiatives address state needs and tie unique education and economic development efforts: *(3)*support standards-based science, mathematics, technology, and geography education change by aligning NASA educational programs and products with the national/state standards: and (4)expand interactions with external stakeholders in the systemic improvement of education change.

A major program at the elementary and secondary education level is the Aerospace Education Services Program (AECSP). The AESP's primary focus is teacher enhancement with emphasis on and support for local, state, regional and national mathematics, science, and technology education efforts through collaboration of internal and external stakeholders in high impact reform activities.

Systemic Improvement activities at the higher education level use partnerships, linkages, and collaborations to provide activities and experiences designed to enhance research and educational capabilities, and enhance the collaborative capabilities of a diverse set of academic institutions. Programs such as Space Grant and EPSCoR play a major role in NASA's contribution toward the Nation's systemic educational reform movement.

The Space Grant Program, authorized by Congress in 1987, increases the understanding, assessment, development, and use of aeronautics and space resources. All 50 states, Puerto Rico, and the District of Columbia have Space Grant Consortium programs in which 703 institutions participate. These consortia form a network of colleges and universities, industry, state/local governments, and nonprofit organizations with interests in aerospace research, training, and education.

The FY 1993 NASA Authorization Act (P.L. 102-588) directed NASA to initiate a program to strengthen the research capability of states that do not successfully participate in competitive space and aeronautical research activities. The NASA EPSCoR Program, modeled after the National Science Foundation's EPSCoR, provides seed funding that will enable eligible states to develop an academic research enterprise directed toward long-term, self-sustaining, nationally competitive capabilities in space science and applications, aeronautical research and technology, and space research and technology programs. This capability will, in turn, contribute to the state's economic viability.

Systemic improvement at both elementary and higher education levels is captured in NASA's Innovative Reform Initiatives program which is supportive of standards-based systemic improvement efforts, and focuses on science, mathematics and technology education. A means of supporting systemic improvement is through partnerships with professional education associations, national aerospace education associations, industries, other Federal agencies, and state and local groups. When NASA becomes a partner with these groups, its role may be one of leadership, being a participant, or acting as a facilitator to empower and enable wide reaching educational reform that is systemic in nature. An example of these partnerships is NASA's work with the National Alliance of State Science and Math Coalitions (NASSMC).

SCHEDULE & OUTPUTS

Performance in this area is measured in a variety of ways, including partnerships/alliances, supplemental funding, and standards. In FY 1998, NASA education activities documented 6,096 alliances with a variety of partners (note, a program may be involved in multiple alliances). Partners included schools (K-12 and higher education), industry, and non-profit organizations. More than $80M was secured in supplemental funding, of which 51% came from other Federal agencies, 11% from state agencies, and 10% from industry/business.

Other measures of performance are indicated below:

Aerospace Education Services Program

- 927 schools visited; 1,513 student programs conducted; 278,559 students involved
- 1,853 teacher workshops conducted; 19,236 teachers participated
- Program was a valuable experience – 4.8 (on a scale of 5, 5=excellent; 1=very poor)
- Workshop content matched school's education objectives – 4.6
- Program demonstrated the interdisciplinary nature of NASA's research and development – 4.7
- Experience increased confidence in subject area – 4.7

Space Grant (FY 1997 data)

- 52 University-based Consortia
- Space Grant involves 703 institutions which include:
  - 493 colleges and universities
  - 62 business/industry
  - 34 State and local government agencies
  - 114 other affiliates (science museums, not for profits, etc.)
- $34.1 M in matching funds (42% university; 21% other Federal, 8% industry; 16% other; 13% local/state government)
- 2,114 fellowships and scholarships (73% undergraduate; 21% underrepresented groups; 43% women)
- 866 education programs/projects/activities
- 331 public service programs/projects/activities

EPSCoR (FY 1997 data)

- Awards to ten states:
  - Alabama, Arkansas, Kentucky, Louisiana, Montana, Puerto Rico – original awardees
  - Kansas, Nebraska, Oklahoma, South Carolina - new in 1996
- Participants:
  - Institutions: 68
  - Research clusters: 47
  - Faculty: 244
  - Post doctoral fellowships: 38
  - Graduate students: 219
  - Undergraduates: 154
- $25.6M proposals funded
- 152 publications, refereed papers
- 2 patents; 5 patent applications; 1 invention disclosure

ACCOMPLISHMENTS AND PLANS

General plans for Systemic Improvement activities in FY 1999 and FY 2000 include providing professional development on standards-based education initiatives to NASA's internal education community; reviewing existing NASA education initiatives to ensure their alignment with the vision and philosophy for state-based systemic reform; designing new programs or redesigning existing programs to ensure that all NASA efforts align with the science, mathematics, technology, and geography education standards and supporting the needs of those engaged in the implementation of standards-based education at the state and local levels; leveraging the use of NASA programs and resources by expanding NASA interactions and cooperation with all stakeholders involved in national and state systemic initiatives; and implementing a plan through the field centers that supports the needs of individual states.

The AESP specialists are directly involved in supporting state systemic improvement by providing technical linkages to NASA research and development and education programs and services. The AESP delivers educational services on a state-by-state basis. Each education specialist is assigned one or two states so they might become familiar with their states' science, mathematics, and technology education agenda and the education leaders within these states. This enables them to customize or tailor-make their teacher workshops to fit that particular state's framework. Funding in FY 1999 will continue operation of this program, although projected reductions will result in fewer teacher workshops conducted around the country.

In FY 1998 and FY 1999, funding for Space Grant was increased pursuant to Congressional direction. This funding increase provides for increased basic awards for all Space Grant consortia and supports the award of designation status to up to four additional state consortia. Since there have been no inflationary adjustments over the years, the increases enable the consortia to continue with elements of their program plans that have been deferred due to lack of growth in the program funding levels

FY 1998 marked the fifth year of the NASA EPSCoR program with continued funding for the original six awardees. These six states have been very successful in a short period of time, as evidenced by the metrics previously cited. In addition, four new states were chosen in the second round of awards in late FY 1996 (Kansas, Nebraska, Oklahoma. and South Carolina). They are completing their second year of work, and are expected to be as successful as the first group. Congressional direction in FY 1999 increased the funding for this program to 10.0M. This will enable all eligible NASA EPSCoR states to receive planning grant funding, and a planning process is currently underway. It is expected that planning grants will be awarded to unfunded states, and continuation grants will be awarded to the original six awardees. These awards will help these programs prepare for the next round of awards, scheduled for FY 2001.

NASA's Innovative Reform Initiatives program supports standards-based systemic improvement efforts and priorities, and focuses on science, mathematics, technology, and geography education. To prevent duplication and to strengthen the impact of systemic reform initiatives, NASA confers with other federal agencies and national organizations that are also working with educational systemic reform, including the National Science Foundation, U.S Department of Education, National Research Council, Council of Chief State School Officers, and professional education organizations such as the National Science Teachers Association, National Council: for the Teaching of Mathematics, and the International Technology Education Association. Systemic reform initiatives are accomplished through partnerships with local, state, and national stakeholders including professional education associations, national aerospace education associations, industries, education agencies, and other interest groups. When NASA becomes a partner with these groups, its role varies between providing supportive leadership, being a complementary participant, or acting as a facilitator to empower and enable wide reaching educational reform that is systemic in nature. Examples of these partnerships are the National Alliance of State Science and Math Coalitions (NASSMC), the Council of State Science Supervisors (CS3), the NASA Industry Education Initiative (NIEI). These partnerships are each mutually beneficial in creating systemic change by increasing the customer and support bases for both NASA and the partnering stakeholder. Similar opportunities will be explored in FY 1999 and FY 2000.

In FY 2000. the AESP and Innovative Reform programs will be maintained at the same funding and participation levels as in FY 1999. The FY 2000 budgets for Space Grant and EPSCoR (13.5M and 4.6M respectively) represent a return to the base level program support. This will result in a decrease in award amounts for Space Grant consortia and a reduction in the number of NASA EPSCoR states receiving funding.

BASIS OF FY 2000 FUNDING REQUIREMENT

EDUCATIONAL TECHNOLOGY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Learning tools.	1,700	1,700	1,700
Demonstrations..	2.000	2,000	2.000
HPCC	4,200	4,000	4,000
Bishop Museum/National Prototype Space Education Curriculum.. ..	2,000	--	--
Alaska Learning Center..	2,500	--	--
Apple Valley, California Learning Center..	1,500	--	--
K- 12 Telecommunications..	6,000	--	--
Louisiana Daily Living Center..	2,000	--	--
Pennsylvania Education Telecommunications Center..	1,500	--	--
California Discovery Science Center..	1,000	--	--
Univ. of Maryland. Advanced Info Tech Center	--	2,000	--
Univ. of Redlands. Academic Infrastructure	--	3,500	--
Residential Aerospace Education Center	--	1,000	--
Total	24,400	14,200	7,700

PROGRAM GOALS

The goal of the Educational Technology program is to research and develop products and services that facilitate the application of technology to enhance the educational process for formal and informal education and lifelong learning.

STRATEGY FOR ACHIEVING GOALS

The Educational Technology program (1) produces technology-based teaching tools and strategies that are grounded in or derived from the NASA mission; (2) uses emerging technologies for, and applies existing technologies to, educational programs: *(3)* utilizes technology to facilitate communication within the educational community; (4) involves educators in **NASA** missions through innovative uses of technologies: and (5) conducts research into new teaching and learning practices that are made possible through NASA mission-derived technology.

The NASA Classroom of the Future (COTF) continues to be the major component of the educational technology program. The role of the COTF is to translate NASA technologies and research results into learning tools, demonstrations, and teacher enhancement programs that support standards-based educatioii reform.

The Learning Technologies Program, provides demonstration projects and on-line systems dedicated to bringing NASA science to teachers and students in the classroom, using examples from NASA's unique missions. The goal of this program is to accelerate the implementation of a national information infrastructure through NASA science, engineering, and technology contributions and facilitate the use of technologies within the K-12 education systems. NASA, led by the Ames Research Center, organizes various interactive on-line projects that connect classrooms with ongoing science and engineering work. The projects provide real and relevant content to enhance classroom curriculums.

SCHEDULE & OUTPUTS

Performance in this area is measured in a variety of ways, including overall quality, type/number of users; standards application; internet hits; data transferred; searchable pages; and unique IP addresses.

- **Educator Resource Center Network**: 142,477 educators used the ERCN (visits, mail, phone, email); 2,018,087 NASA education materials disseminated; teacher ratings of teacher guides – 4.81 (1=lowest; 5=highest); 1,217 site workshops conducted with 27,945 participants.
- **NASA Spacelink, NASA Quest, and Learning Technologies Program**: 199,636,397 internet hits; 28,379 GB data transferred; 6,431,900 unique IP addresses
- Research and Development: **Classroom of the Future**. Two major instructional CD-ROMS, BioBlast and Astronomy Village, were developed and dissemination begun; one web-based Earth science curriculum supplement; one on-line course for Earth science teachers; 25,000 materials disseminated; 15,000 students and 7,000 teachers served.

ACCOMPLISHMENTS AND PLANS

General plans for this program area include providing technology training and support for the persons involved in the operation of the Educator Resource Center Network and the Space Grant program; implementation of a coordinated electronic dissemination system that ensures that all NASA education activities and products are available through appropriate networking technologies; demonstrate NASA's educational technology resources at professional development conferences; develop innovative learning tools and technologies that are integrated with curriculum support and teacher enhancement activities ; develop, implement, and evaluate distance education and virtual mentoring projects; and support distribution of excess NASA equipment to schools and institutions of higher education.

Educational Technology activities support the development of high quality, affordable learning tools and environments (e.g., CD-ROM databases, DVD-ROM, live or taped video, computer software, multimedia systems, virtual reality) and supplementary instructional materials. These tools use existing technology as well as emerging technologies to facilitate education programs. Demonstrations of innovative, efficient, and effective technology and networking applications are also supported. Classroom of the Future continues to be NASA's primary educational technology research and development site.

NASA's Educational Technology program includes the center-based components of the Learning Technologies Program (LTP). One of the goals of this program is to demonstrate how newly emerging communication technologies can be used to bring NASA's science and engineering data to schools and the public. The ten center-based projects have made extensive amounts of earth, space, and aeronautics information available on the Internet in educational formats. Through this program, collaborations are maintained with and support provided to schools across the country. In FY 1999 LTP will initiate a follow-on grant program funding the use of information technology in educational outreach efforts.

Educational Technology activities in FY 1998 included funding for the following activities directed by Congress in the Conference Report accompanying the FY 1998 VA-HUD-Independent Agencies Appropriation Act: National Prototype Space Education Curriculum in conjunction with the Bishop Museum in Hawaii; Alaska Learning Center; California Learning Center in Apple Valley; K-12 telecommunications in San Bernardino, Louisiana Daily Living Center, Pennsylvania Education Telecommunication Center, and California Discovery Science Center. In FY 1999, additional activities directed by Congress include the University of Maryland Advanced Information Technology Center, University of Redlands Academic Infrastructure, and Residential Aerospace Education Center.

In FY 2000, Educational Technology programs will be maintained at the same funding and participation levels as in FY 1999.

BASIS OF FY 2000 FUNDING REQUIREMENT

EVALUATION

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Evaluation..	700	700	700

PROGRAM GOALS

The goal of the evaluation program is: to provide documented evidence of the degree to which NASA's educational program, with its associated projects and activities, has accomplished its goals; and to develop a systematic strategy for collecting, aggregating, and reporting evaluation indicator data.

STRATEGY FOR ACHIEVING GOALS

NASA has undertaken a comprehensive effort to evaluate its education programs in order to demonstrate the accomplishment of achievable and measurable goals and objectives. A set of standard, Agency wide indicators, metrics, and evaluation instruments has been developed for Agency wide use. The data are collected on-line in a single database capable of providing correlation and report generation capability. External education evaluation experts provide guidelines and criteria for the analysis of qualitative and quantitative data to facilitate an in-depth survey of various programs offering recommendations and suggestions about the instruments in development.

SCHEDULE & OUTPUTS

NASA continues to refine a comprehensive system to evaluate its Education Program in order to demonstrate the accomplishment of achievable and measurable goals and objectives. Based on recommendations provided by a study of the NASA Education Program by the National Research Council (NRC), NASA established program goals and defined a comprehensive Education Framework that captures the elements of NASA's Education Program. This framework is detailed in NASA's *Implementation Plan for Education*, and supported by implementation plans developed by the Enterprises and NASA field installations between FY 1995 and the present. NASA utilizes an Internet-based system, for the collection, analysis, evaluation and reporting of standard and program unique data and program outcomes for all NASA education programs. This system, the NASA Education Data Collection and Evaluation System (EDCATS) has completed three field test years, each year capturing additional programs and data.

ACCOMPLISHMENTS AND PLANS

NASA's Education Data Collection and Evaluation System (EDCATS), operational in FY 1998, continues to add programs incrementally until all NASA education programs are included. As programs compile a firm set of baseline data, selected annual program targets will be established, as needed or required. Funding included in FY 1999 and FY 2000 will support the continuation and improvement of the system. By FY 2000 the system will be fully operational to track data and evaluation metrics for the entire NASA Education Program.

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS — **MINORITY UNIVERSITY RESEARCH AND EDUCATION PROGRAM**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Historically Black Colleges and Universities	30,000	36,200	28,000	SAT 6.2-10
University Research Center Awards	200	--	--	
Institutional Research Awards	--	1,000	3,200	
Principal Investigator Awards	4,600	5,200	4,500	
Math and Science Education Awards	16,200	14,500	18,500	
Partnership Awards	9,000	15,500	1,800	
Enterprise Program Funding *	[12,800]	[17,100]	[17,100]	
Other Minority Universities	23,200	30,700	17,900	SAT 6.2-15
Institutional Research Awards	2,000	500	1,500	
Principal Investigator Awards	2,500	3,100	3,600	
Math and Science Education Awards	15,000	18,500	11,700	
Partnership Awards	3,700	8,600	1,100	
Enterprise Program Funding *	[8,000]	[11,700]	[11,700]	
Total Minority University Research Programs	53,200	66,900	45,900	
Total Enterprise Program Funding *	[20,800]	[28,800]	[28,800]	
Total Program Funding to Minority University Research	74,000	95,700	74,700	

* Represents funding included in Enterprise budget request in support of Minority University Programs

SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

ACADEMIC PROGRAMS | **MINORITY UNIVERSITY RESEARCH AND EDUCATION PROGRAM**

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Distribution of Program Amount by Installation			
Johnson Space Center	2,500	2,900	2,200
Kennedy Space Center	4,100	5,700	4,300
Marshall Space Flight Center	8,700	5,700	4,900
Stennis Space Center	1,500	3,200	2,600
Ames Research Center	700	2,500	1,900
Dryden Flight Research Center	1,500	3,100	2,300
Langley Research Center	2,700	5,400	4,300
Glenn Research Center	7,600	13,300	2,100
Goddard Space Flight Center	21,700	22,100	18,700
Jet Propulsion Laboratory	1,400	3,000	2,600
Headquarters	800	--	--
Total	53,200	66,900	45,900

PROGRAM GOALS

The Minority University Research and Education Programs (MUREP) focus primarily on expanding and advancing NASA's scientific and technological base through collaborative efforts with Historically Black Colleges and Universities (HBCU) and Other Minority Universities (OMU), including Hispanic-Serving Institutions (HSI) and Tribal Colleges and Universities (TCU), hereafter referred to as Minority Institutions (MI). NASA's outreach to MI's in FY 2000 will build upon the prior years' investments in MI research and academic infrastructure. Through sufficient infrastructure-building support, exposure to NASA's unique mission and facilities, and involvement in competitive peer review and merit selection processes annually, MI's will be able to contribute significantly to the Agency's strategic goals and objectives. These contributions include the education of a more diverse resource pool of scientific and technical personnel who will be well prepared to confront technological challenges for the benefit of NASA and the Nation. In addition to the Federal mandates for MI's, the strategic goals that guide NASA's MUREP are: (1) To foster research and development activities at MI's which contribute substantially to NASA's mission; (2) To create systemic and sustainable change at MI's through partnerships and programs that enhance research and educational outcomes in NASA-related fields; (3) To prepare faculty and students at MI's to successfully participate in the conventional, competitive research and education process; and (4) To increase the number of students served by MI's to enter college and successfully pursue and complete degrees in NASA-related fields.

STRATEGY FOR ACHIEVING GOALS

NASA employs a comprehensive and complementary array of strategies to achieve these goals for MI's. These strategies include: (1) Working closely with NASA Strategic Enterprises, other government agencies, and interested parties to develop new research and education collaborations and partnerships; (2) Encouraging and providing opportunities for faculty to conduct NASA research early in their careers; (3) Providing incentives for students to enter and remain in mathematics, science and technology disciplines; (4) Establishing measurable program goals and objectives; and (5) Developing and implementing evaluations to assess the effectiveness and outcomes of the programs and financial performance, and thereby improving program delivery and results.

A strategy used to expand MI involvement in competitive peer review processes and to ensure the relevance of research conducted by MI's is to involve NASA Strategic Enterprises early in the development of solicitation notices. Once Headquarters issues the notices, NASA Centers provide advice to prospective grantees, conduct peer reviews of proposals, and provide funding recommendations to the Office of Equal Opportunity Programs (OEOP) and the Strategic Enterprises. After Headquarters makes the selections, the research is returned to the nominating NASA Center(s) or Jet Propulsion Laboratory (JPL) for grant award and technical management of the award. OEOP provides policy direction and program oversight. Oversight of the research performed at MI's is conducted by the Strategic Enterprises in collaboration with OEOP. In addition, all MUREP requests for continuation funding are assessed for performance by the NASA Technical Officers and all awards funded for more than 2 years receive on-site reviews.

The successful deployment of these strategies has resulted in the establishment of five different programmatic award categories which apply equally to the HBCU and OMU MI Programs. These award categories are: (1) University Research Centers (URC) Awards; (2) Institutional Research Awards (IRA); Principal Investigators (PI) Awards; (4) Mathematics and Science Education (MSE) Awards; and (5) Partnership Awards.

University Research Center (URC) Awards

University Research Center (URC) Awards achieve a broad-based, competitive aerospace research capability among the Nation's MI's that will: foster new aerospace science and technology concepts; expand the Nation's base for aerospace research and development; develop mechanisms for increased participation by faculty and students in mainstream research; and increase the productivity of students (who are U.S. citizens and who have historically been underrepresented) with advanced degrees in NASA-related fields. Funding is provided by the Strategic Enterprises. In order to foster closer ties between the URC's and NASA, a Lead NASA Center is designated for each URC that is responsible for directly managing the URC cooperative agreements, and for increasing MI involvement in ongoing NASA research and development activities. Collaborations with other NASA Centers, industry, and other universities are strongly encouraged. OEOP continues to maintain responsibility for program policy and oversight. The URC's have formed a National Alliance of NASA University Research Centers (NANURC). This Alliance has established a National Conference of the University Research Centers, created pathways for developing greater collaborations between the URC's, and is exploring avenues for increasing the number of advanced degrees being awarded to disadvantaged students. NASA is strongly supportive of this concept and is actively working with the Alliance to further develop and strengthen their organization.

Institutional Research Awards (IRA)

Institutional Research Awards (IRA) improve academic, scientific and technology infrastructure and broaden the NASA-related science and technology base at MI's. Two awards with different focus areas have been made under this category. The first IRA (Research) award was made in FY 1994 and was limited to only OMU's. These awards provide OMU's with an opportunity to provide a quality learning and research environment in NASA-related areas. The second IRA (Network Resources and Training Sites [NRTS]) were open to all MI's. The IRA (NRTS) award is designed to improve the in-house capability to electronically access science data and computational resources; to develop mechanisms to support, sustain and evolve the network infrastructure of the targeted universities and colleges; and to make MI's more effective in the competitive process for NASA and other science, engineering and technology funding opportunities. IRA awards provide for the acquisition of research equipment and equipment essential to Internet connectivity. The strategies for achieving the IRA (NRTS) goals include: (1) Establishing lead NRTS's (2) Holding them accountable for providing internet connectivity to other MI's and public schools; and (3) For training students, faculty and teachers to build computers, maintain and effectively utilize the Internet to compliment teaching and research collaborations and delivery. Goddard Space Flight Center (GSFC), manages the IRA (NRTS) under the auspices of GSFC's Minority University - Space Interdisciplinary

Network (MU-SPIN) Program. The Offices of Equal Opportunity Programs (OEOP), Space Science, and Earth Science collaboratively provide funding and oversight for the GSFC MU-SPIN Program. NASA Strategic Enterprises, NASA Centers, and JPL support IRA programs through direct funding, use of their facilities, and commitment of their personnel to serve on Technical Review Committees (TRC) and assisting in other facets of program implementation. Students and principal investigators involved in IRA (NRTS) spend time on-site at the Centers and JPL throughout the year.

Principal Investigators (PI) Awards

Principal Investigators (PI) Awards provide faculty with limited NASA experience, an opportunity to integrate the research and education components of their careers with the unique mission requirements of a specific NASA Center or JPL. Each fiscal year, MI's are invited to submit proposals for the Faculty Awards for Research (FAR). The FAR program provides for competitive, peer review selection of outstanding and promising engineering, physical and life science-tenured and tenure-track faculty who are capable of contributing to the Agency's research and education objectives. This award provides faculty members with research support and exposure to the NASA peer review process to enable them to demonstrate creativity, productivity, and future promise in the transition toward achieving competitive awards in the Agency's mainstream research processes. In FY 1996, these awards were expanded to include funding to involve graduate and undergraduate students in research projects.

The primary strategy for implementing the PI Awards for Research is through a competitive peer review and merit selection process in collaboration with the Strategic Enterprises, NASA Centers and JPL. Other strategies include: (1) Have discipline-related personnel at Headquarters and the NASA Centers and JPL be responsible for serving as points-of-contact for faculty interested in pursuing an award in this category; (2) Place responsibility on the interested NASA Centers or JPL for conducting the technical evaluations and making recommendations to Headquarters for funding consideration; (3) Provide funding to the nominating NASA Center or JPL to make PI Awards for Research; and (4) Hold the NASA Center or JPL responsible for managing the awards and research outcomes. By involving MI faculty and students in NASA research, the Agency hopes to increase the interest of traditionally underrepresented communities in the Agency's mission and involve a broader array of America's citizenry in the NASA-sponsored research community.

Mathematics and Science Education (MSE) Awards

Mathematics and Science Education (MSE) Awards build upon these institutions' outstanding ability to provide excellence in mathematics, science, engineering and technology (MSET) training while increasing the participation and achievement of socially and economically disadvantaged and disabled students in MSET fields at all levels of education. Awards are made in the following three areas: undergraduate and graduate; teacher preparation and enhancement; and precollege activities.
MSE Awards contribute to the national education goals by integrating the contents from the NASA mission into the educational outreach projects at MI's. As a result, NASA contributes to an increase in the number and strengthens the skills, knowledge, and interest of students and teachers in mathematics-, science-, engineering-, and technology-based (MSET) academic programs. MSE awards consist of both unsolicited and solicited awards. The solicited awards are the NASA Precollege Awards for Excellence in Mathematics, Science, Engineering and Technology (PACE/MSET) Program and the Mathematics, Science, and Technology Awards

for Teacher and Curriculum Enhancement Program (MASTAP). Both types of MSE awards are reflected in the following subcategories:

- Undergraduate and Graduate Awards provide scholarships, fellowships, internships, and research opportunities in NASA-related fields, and other services to enhance retention and increase graduation rates. These awards respond to congressional direction to increase the number of individuals from underrepresented groups in the pool of graduate researchers. Students must be U.S. citizens and must pursue degrees in NASA-related fields. During the academic year and/or summer, students are required to conduct research relevant to their fields of study at a NASA Center, on a university campus, at a Federal laboratory or in the aerospace industry. It is expected that these students will form part of the pool from which NASA selects graduate researchers and/or employees.

- Teacher Preparation and Enhancement Awards provide opportunities for MI's to develop diverse and exemplary research-based mathematics, science, technology and geography teacher education curricula, integrated with content from NASA's mission. It is the Agency's desire that the results from these awards serve as models for other colleges and universities. Additionally, these awards will contribute to the participating states' efforts to increase the numbers and percentage of state-certified mathematics, science, technology or geography teachers employed in hard-to-staff elementary, middle and secondary schools not normally served by NASA.

- Precollege Awards provide opportunities for MI's, in collaboration with NASA and local school districts, to provide informal educational opportunities that will enhance the numbers and percentage of students enrolled in mathematics and science college preparatory courses. As a result of participating in these awards, students will gain awareness of career opportunities in MSET fields and exposure to NASA's mission and scientific and technical personnel role models.

Partnership Awards

Partnership Awards design to respond to congressional direction to "expand opportunities and enhance diversity in the NASA sponsored research and education community...achieve a balance between the proportion of NASA funding received by minority institutions of higher education and other institutions of higher education." The goals of the Partnership Awards program are to achieve the following outcomes: 1) More competitive undergraduate U.S. students with research training, who are exposed to NASA cutting-edge technology, and who are better prepared to enter MSET graduate programs or MSET careers; 2) Enhanced undergraduate courses and curriculum, including laboratory-based curricula that foster collaboration between NASA-funded research and education faculty; 3) Produce model HBCU's that integrate NASA-related research into appropriate areas of the undergraduate curriculum; and 4) to strengthen NASA Centers' and JPL's partnerships with OMU's through projects which are unique and innovative, which fall outside of the usual MUREP competitive programs, and which have high potential for long-term support from other sources. The NASA Centers and JPL are invited to jointly submit, with Presidents of Minority Universities, proposals in three different categories: research; education; or combination of the two to Headquarters for competitive review and selection. All proposals selected for an award must be responsive to the Agency's strategic direction; the Federal mandates related to MI's; and the NASA MUREP goals. Additional funding of $9.4M was included in the FY 1999 Appropriation Bill for VA-HUD-

Independent Agencies to continue and expand the Partnership Award program and is divided between the HBCU and OMU programs.

All of the above programmatic initiatives are carried out in strong collaboration with NASA Strategic Enterprises, Centers and JPL. Strategic Enterprises, Centers, and JPL support the MUREP through direct funding, use of their facilities, and commitment of their personnel to serve on Technical Review Committees (TRC) and assist in other facets of program implementation. URC's and IRA's receive technical guidance and annual on-site reviews by TRC's. The PI, MSE, and Partnership Awards are managed predominately by personnel at the NASA Centers and JPL. As a result of the involvement of the Strategic Enterprises, NASA Centers and JPL in the MUREP, numerous students and PI's from MI's are knowledgeable about and make significant contributions to the Nation's space program.

In FY 2000, all five programmatic award categories will have activities to replace expiring awards with new competitive peer reviewed and selected awards. Outreach to MI's will continue to be made in collaboration with the Strategic Enterprises, Centers and JPL to ensure that MI's are knowledgeable of and responsive to the Agency's strategic plan. OEOP will continue to set specific program goals that lead to measurable program outcomes that are consistent with the Agency's investment in MI's.

SCHEDULE & OUTPUTS

MUREP metrics are continually being improved. Performance data measuring participation and program outcomes is obtained through the required submission of annual performance reports and/or on-site or reverse-site reviews of each award. Each grant recipient submits an annual performance report that is reviewed by a NASA Technical Monitor or a Technical Review Committee for qualitative and quantitative progress toward the project's and NASA's program goals and objectives. Continuous assessment of this data has enabled OEOP MUREP to identify performance measures for research and education awards. As part of the grantee's annual reporting requirements, each awardee is now being required to respond to a set of uniform research or education outcomes that enables OEOP to assess progress across all research or education awards. Additionally, as required by Executive Order 12876 for HBCU's and Executive Order 12900 for HSI's, at the end of each fiscal year, NASA measures its performance against the concluding fiscal year plan that was submitted to the White House Initiative Office and the Office of Management and Budget. The measures of performance include the number of awards and funding to HBCU's and HSI's in the following categories: research and development; program evaluation; training; facilities and equipment; fellowships, internships, traineeships, recruitment and IPA's; student tuition assistance, scholarships, and other aid; direct institutional subsidies; third-party awards; private-sector involvement; and administrative infrastructure.

The objectives are to establish uniform outcomes for all NASA MUREP awards and provide compact instruments for uniform collection of data keyed to those outcomes. This process reduces the collection of data to the minimal amounts possible, emphasizes outcomes and is applicable to any common set of awards. The data collected can be aggregated both horizontally and longitudinally, permits adjustable benchmarking standards to be applied, and is collected electronically over the World Wide Web. A single annual collection of data is used to provide the information necessary for comparative and correlational analysis across research or education projects, and annual MUREP performance reports, including those required by the White House Initiative Offices on HBCU's, Educational Excellence for Hispanic Americans, and Tribal Colleges and Universities. Based on prior years' evaluation results, the following uniform measures of performance have been established for OEOP MUREP research and education awards.

RESEARCH SCHEDULE & OUTPOUTS (for URC's, IRA's, PI's, and Partnership (Research) Awards)

- Participants – number of students, faculty, post-doctoral researchers, research associates supported
- Student Outcomes – number of degrees awarded, post-graduation plans
- Research Outcomes – number of referred papers, technical presentations, patents, commercial products, and amount of research funds leveraged from other sources

EDUCATION AND TRAINING SCHEDULE & OUTPUTS (for MSE's and Partnership (Education) Awards)

- Participants - number of students, teachers supported
  - High School Student Outcomes - enrollment in Mathematics, Science, Education and Technology (MSET) courses, graduation, enrollment in college, and selection of MSET majors
- Bridge Student Outcomes - completed freshman year in college
- Undergraduate & Graduate Student Outcomes - number of degrees awarded, post-graduation plans
- Teacher Outcomes - number of received certificates

IRA (NRTS) additional metrics are designed to capture the technology and education focus of these awards. Specific metrics will include:

- The number of HBCU's, OMU's, and public schools connected to the Internet
  - The number of faculty, teachers and students trained to utilize the Internet to enhance research and educational outcomes

Continuous assessment of performance, through annual evaluations of individual awards and the collection of uniform outcomes across all research and education programs, will clearly indicate the impact of NASA MUREP on the scientific and technological base for NASA and the Nation, while minimizing the reporting burden on award recipients.

ACCOMPLISHMENTS AND PLANS

NASA's investment in MI's for FY 1998 achieved the following:

1. Funding reached 45 states, the District of Columbia, Puerto Rico, and the Virgin Islands.
2. The number of competitively peer-reviewed and merit selected MUREP awards totaled 59 in FY 1998.
   - 3. 42 HBCU's were the direct recipients of 169 research and education awards valued at $31.3M. 30 OMU's received 26 awards valued at $11.4M. Other institutions of higher education and non-universities received $12.1M in support of outreach activities to minorities and individuals with disabilities underrepresented in NASA career fields. These awards included:
   - 72 awards to 20 HSI's at $10.3M
   - 10 awards to 8 Tribal Colleges and Universities at $1.1M

- 88 awards to other institutions of higher learning
- 11 awards to non-universities such as the National Research Council, American Association for the Advancement of Science, American Society for Engineering Education, National Association for the Advancement of Equal Opportunity in Higher Education, etc.

Research Accomplishments included the following number of participants: 396 faculty members, 130 research associates, 35 postdoctoral fellows, 664 undergraduates, and 419 graduates. The MI's were able to leverage their NASA MUREP funding of $31.2 million (including $6.6 million for students) to an additional $33.7million in research support, $11.4 million from other NASA programs, and $22.3 million from other agencies. Technology transfer activities reported included 23 patent awards, 28 patent applications, and 27 patent disclosures; and 37 commercial products being developed or marketed. A major goal of MUREP is to increase the number of socially and economically disadvantaged and disabled students receiving advanced degrees and entering into careers in NASA-related fields. Of the 1,084 students involved in these research projects during the reporting period, 664 (61%) participated at the bachelor's-degree level, 299 (28%) participated at the master's-degree level, and 120 (11 percent) participated at the doctoral-degree level. During the reporting period, 363 students obtained degrees: 220 bachelor's degrees; 116 master's degrees; and 27 doctoral degrees.

In Education and Training area, NASA MUREP grantees were asked to respond to the above-listed measures of performance via the web to provide a clearer, more concise reporting mechanism across all of the grants. The Uniform Outcomes Report also was designed to avoid duplication of reporting requirements by serving as the grantees' annual performance report. The outcomes reported for FY 1998 (reporting period Academic Year 1997–98 and Summer 1998) show great achievements for underrepresented and under served students, teachers and faculty. There were 230 MUREP education and training projects conducted at Minority institutions. The programs included precollege and bridge programs, education partnerships with other universities, industry and nonprofit organizations, Network Resources Training Sites (NRTS), teacher training, and graduate and undergraduate programs. These programs reached a total of 46,638 participants, with the predominant number at the precollege level. The programs achieved major goals of heightening students' interest and awareness of career opportunities in MSET fields, and exposing students to the NASA mission, research and advanced technology through role models, mentors, and participation in research. Formats included Saturday Academies, after school classes, visits to NASA Centers and other scientific and technical industries, museums, hands-on science experiments and computer training. Many projects also included components in English, writing, public speaking, and data analysis with the goal toward developing a well-grounded student.

Grantees reported that 12,681 high school students participated in NASA programs and 6,512 high school students selected college preparatory MSET courses. There were 1,482 high school graduates and 237 bridge students (high school graduates) in NASA programs. One thousand thirty four students enrolled in college, and 345 selected MSET majors. There were 171 students who successfully completed their freshman year. For the teacher programs, 2,396 teachers participated and 206 teachers received certificates. For undergraduate student programs 4796 students participated, 145 received degrees, 43 are employed in a NASA-related field. There were 112 graduate students participating in graduate programs, 22 received degrees, and 31 became employed in a NASA-related field. There were 33 papers published, 15 of which were authored or co-authored by students. One hundred seventy nine presentations were given at NASA installations, and 213 presentations at national or international conferences.

During FY 1999, NASA MUREP will continue to focus on its goals and strategies to integrate mission-focused research, technology transfer, and education at HBCU's and OMU's. NASA will continue and expand partnership awards that leverage NASA's investment by encouraging collaboration among NASA, university researchers and educators, and the aerospace industry. Plans for new awards include new Individual Principal Investigator's Research awards and Math and Science awards. The financial investment of $28.8M by NASA Strategic Enterprises is planned for FY 1999.

In FY 2000, as in FY 1999, NASA MUREP will continue to focus on its goals and strategies to integrate mission-focused research, technology transfer, and education at HBCU's and OMU's. NASA will emphasize partnership awards that leverage NASA's total research investment in higher education institutions and aerospace industry. NASA will continue to increase the number of solicited awards that are selected through the peer review award process. Plans for new awards categories are dependent upon the number of expiring awards. It is forecasted that expiring awards will provide opportunities for new Institutional Research Awards, Individual Principal Investigator's Research, Math and Science Education Partnership Awards. The Strategic Enterprises investment will remain $28.8M. The technical involvement by NASA Strategic Enterprises research conducted by HBCU's and OMU's will continue.

BASIS OF FY 2000 FUNDING REQUIREMENT

HISTORICALLY BLACK COLLEGES AND UNIVERSITIES

	FY 1998	FY 1999 (Thousands of Dollars)	FY 2000
University Research Centers	200	--	--
Institutional Research Awards	--	1,000	3,200
Principal Investigator Awards	4,600	5,200	4,500
Math Science and Education Awards	16,200	14,500	18,500
Partnership Awards	9,000	15,500	1,800
Total Minority Programs	30,000	36,200	28,000
Enterprise Program Funding*	12,800	17,100	17,100
Total, Historically Black Colleges and Universities	42,800	53,300	45,100

* Represents funding included in Enterprise budget request in support of Minority University Programs

PROGRAM GOAL

NASA's HBCU program is responsive to Executive Order 12928, which require all Federal Agencies to strengthen the capacity of HBCU's to provide quality education and to participate in and benefit from federal programs. The primary goal of NASA's HBCU program is to enhance institutional infrastructure in NASA-related areas and to provide technical assistance to facilitate planning, development, and the use of new technologies that will ensure the long-term viability and educational outcomes of HBCU's in areas strategic to NASA's mission.

STRATEGY FOR ACHIEVING GOALS

HBCU's were involved in NASA's mission before humans set foot on the Moon in 1969. In 1980, President Jimmy Carter signed Executive Order 12232 that established a Federal program "...to strengthen and expand the capacity of HBCU's to provide quality education." Executive Orders issued by Presidents Ronald Reagan and George Bush strengthened this program. NASA's current initiatives for HBCU's are based upon two recent Executive Orders. Executive Order 12876, signed November 1, 1993, by President William J. Clinton, mandates that agencies ". Advance the development of human potential, to strengthen the capacity of HBCU's to participate in and benefit from federal programs to achieve an increase in the participation by HBCU's in federal programs." Executive Order 12928, signed February 16, 1994, by President Clinton directs Federal agencies to promote procurement with "...Historically Black Colleges and Minority Institutions." NASA employs a comprehensive strategy to accomplish the HBCU program goals. This approach is carried out through awards in five areas:

ACCOMPLISHMENTS AND PLANS

As a result of NASA's FY 1998 investment in HBCU's, 42 HBCU's were the recipient of 169 awards that reached more than 26,000 faculty, teachers and students. Specific accomplishments for each of the categories are as follows:

FY 1998 Accomplishments	University Research Centers	Principal Investigators	Partnership Awards
Research Population Supported:	551	352	283
Faculty Members	134	63	72
Research Associates	31	33	16
Postdoctoral Fellows	12	2	8
Bachelor-degree Level Students	211	183	135
Master's-degree Level Students	113	62	39
Doctoral-degree Level Students	50	9	13
Degrees Awarded:	127	56	64
Bachelor Degrees	78	30	49
Master's Degrees	40	20	14
Doctoral Degrees	9	6	1
% Socially/Economical Disadvantaged or Disabled	92%	80%	80%
Research Accomplishments:			
Refereed Papers or Book Chapters:			
Published	172	46	27
Student (Co) Authors to above	78	26	11
Accepted for Publication	79	23	14
Student (Co) Authors to above	34	27	11
Technical Presentations:			
Total Presentations	500	184	127
Presentations given by Students	152	52	25
Leverage Achieved (in $M):			
Funding Provided by MUREP	$13.0	$3.8	$3.5
Leverage from Other NASA Programs	$4.9	$1.2	$0.5
Leverage from Other Agencies	$9.0	$3.2	$2.1

Technology Transfer Activities:			
Patents disclosed, applied for, or awarded	3	23	11
Commercial products being developed/marketed	4	7	8
Grant Awards Reporting	14	58	24

The FY 2000 budget estimate includes funding to continue HBCU's involvement in all five award categories.

HBCU University Research Centers (URC) Awards

Eleven HBCU Research Centers were established by the Headquarters Office of Space Science (OSS); Office of Aero-Space Technology (OAST); Office of Space Flight (OSF); Office of Microgravity and Life Sciences (OMLS); Office of Earth Science (OES), and the Office of Equal Opportunity Programs (OEOP). Funding is provided in two stages, the amount depending on the universities' capabilities. In the first stage, more funding is provided to establish a research infrastructure capable of sustaining long-term success in their research and education efforts (up to $2M per university). The funding is reduced in the second stage (not to exceed $1M per university) to recognize and encourage the movement of the URC's towards self-sufficiency through other funding sources. In FY 2000 funding for the following HBCU URC's will continue to be provided by the Strategic Enterprises.

University	Research Focus	Enterprises	Lead NASA Installation
Clark Atlanta	High Performance Polymers & Composites Research	OAST	Glen Research Center
Fisk	Photonic Materials and Devices	OSS	Marshall Space Flight Center
Florida A&M	Nonlinear and Nonequilibrium Aeroscience	OAST	Langley Research Center
Hampton University	Optical Physics	OSS, OES	Langley Research Center
Howard University	Study of Terrestrial and Extraterrestrial Atmospheres	OSS, OES	Goddard Space Flight Center
North Carolina A&T State	Aerospace Research	OAST	Langley Research Center
Tuskegee University	Food and Environmental Systems for Human Exploration of Space	OAST	Johnson Space Center
Alabama A&M	Hydrology, Soil Climatology, and Remote Sensing	OES	Marshall Space Flight Center
Morehouse School of Medicine	Space Medicine and Life Sciences	OLMSA	Johnson Space Center
Prairie View A&M	Applied Radiation Research	OSF	Johnson Space Center
Tennessee State	Automated Space Science	OSS	Goddard Space Flight Center

HBCU Institutional Research Awards (IRA)

Five HBCU's received renewal awards in FY 1998 for IRA (NRTS) from the OES, OSS and OEOP. These lead NRTS are part of a network that encompasses seven regions that cover the 50 states, Puerto Rico and the Virgin Islands. A minimum of two faculty/teacher/student regional training workshops per institution were held this year. GSFC serve as the Lead Center for the IRA NRTS Program. The lead NRTS' universities are: Prairie View A&M, Elizabeth City State, Morgan State, South Carolina State, and Tennessee State.

In FY 2000, OES, OSS and OEOP will continue funding for the five HBCU IRA (NRTS) selected to bring advanced computer networking infrastructure and technologies to other institutions of higher education and schools with substantial enrollments of socially and economically disadvantaged and disabled students in their regions. These institutions are responsible for information dissemination sites, developing faculty and student network skills, and user working groups.

HBCU Principal Investigator (PI) Awards

The PI Awards for Research are composed of MUREP solicited (also known as Faculty Awards for Research or FAR) and unsolicited (or Other Research and Technology) awards. FAR grants provide for research and student support and exposure to the NASA peer review process to enable them to demonstrate creativity, productivity, and future promise in the transition toward achieving competitive awards in the Agency's mainstream research activities. The number of unsolicited awards depends on funding provided to MUREP, with the priority being on FAR awards.

The majority of HBCU research selected for funding is made through competitive peer review and merit selection processes to enhance opportunities for participation in the Agency's mainstream research capabilities are enhanced through interaction with NASA researchers and faculty. Additionally, the pool of socially and economically disadvantaged students with research experience and interest in pursuing advanced MSET degrees in the fields of science, engineering, and mathematics will increase through faculty support. In FY 2000, 10 second year FAR awards will be continued and 10 new FAR awards will be selected.

HBCU Math and Science Education Awards

During the FY 1998 reporting period (Academic Year 1997-98 and Summer 1998), 98 MUREP education and training projects were conducted at HBCU institutions. The programs included precollege and bridge programs, education partnerships with other universities, industry and nonprofit organizations, NRTS, teacher training, and graduate fellows and/or undergraduate programs. These programs reached a total of 24,512 participants, with the predominant number at the precollege level. The programs achieved major goals of heightening students' interest and awareness of career opportunities in MSET fields, and exposing students to the NASA mission, research and advanced technology through role models, mentors, and participation in research and other educational activities. The reported outcomes on the survey were as follows. Grantees reported 5,359 high school students in NASA programs and 3,002 high school students selected college preparatory MSET courses, 624 high school graduates, 452 enrolled in college, and 212 selected MSET majors. There were 836 high school graduates (bridge students) in NASA programs and 117 students who successfully completed their freshman year. There were 1382 teachers in teacher programs and 90 teachers received certificates. For undergraduate student programs of 2745 students, 67 received degrees, 25 are continuing for the next degree, 27 are employed in a NASA-related field. There were 38 graduate students reported in the survey, 9 received degrees, and 2 employed in a NASA-related field. There were 14 papers published, 8 of which were authored or co-authored by students. Ninety-five students gave presentations at NASA Installations, and 74 students presented at a national/international conference.

In FY 2000, three third year and five second year MASTAP awards will be continued. Eleven third year and eleven second year PACE awards will be continued. Ten new HBCU MASTAP and/or PACE awards will be selected to replace expiring awards in FY 2000.

Additional funding of $1.6M was included in the FY 1999 Appropriation bill for VA-HUD-Independent agencies for a grant to Morgan State University (MSU) for capital renovations and environmental remediation at the University's multipurpose facitlity to facilitate its effective use for the conduct of math and science education workshops to at-risks students in middle and high school. Once a proposal is received from MSU, NASA projects the award to be made to MSU by the beginning of the third quarter of FY 1999. As a result, funds will be available for this award through FY 2000.

HBCU Partnership Awards

In FY 1998, 45 Partnership Awards to HBCU in 14 states and the District of Columbia were continued. Four new Partnership Awards for the Integration of Research into Undergraduate Education (PAIR) were competitively awarded to HBCU's. In FY 1999, the Partnership Awards selected in FY 1997 will receive their last year funding, and the four PAIR selected for five year awards will receive second year funding. Expiring Partnership Awards recipients will have an opportunity to competitively apply for new funding under a NASA Research Announcement. All NASA Centers and Jet Propulsion Laboratory will accept proposals, conduct the review, recommend awards for selection, and continue to manage the Partnership Awards. In FY 2000, the newly selected Partnership Award recipients will receive second year funding, the PAIR third year funding, and two new PAIR awards will be made during FY 2000.

BASIS OF FY 2000 FUNDING REQUIREMENT

OTHER MINORITY UNIVERSITIES

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Institutional Research Awards	2,000	500	1,500
Principal Investigator Awards	2,500	3,100	3,600
Math Science and Education Awards	15,000	18,500	11,700
Partnership Awards	3,700	8,600	1,100
Total Minority Programs	23,200	30,700	17,900
Enterprise Program Funding *	8,000	11,700	11,700
Total, Other Minority Universities	31,200	42,400	29,600

*Represents funding included in Enterprise budget request in support of Minority University Programs

PROGRAM GOAL

The primary goal of NASA's OMU program is to increase the opportunities for Hispanic-Serving Institutions (HSI's), Tribal Colleges and Universities (TCU) and educational organizations serving substantial numbers of people with disabilities to participate in and benefit from NASA's research and education programs.

STRATEGY FOR ACHIEVING GOALS

NASA established the OMU program per P. L. 98-371, House Report 98-803, and Senate Report 98-506) to "...review institutions of higher learning having significant minority enrollments to find ways to build closer relations with such schools, meet NASA's research objectives and increase the number of individuals from underrepresented groups in the pool of graduate researchers...build a closer relationship with institutions serving significant numbers of minorities. In addition, Executive Order 12900 (February 22, 1994) mandated that agencies increase Hispanic American participation in Federal education programs where Hispanic Americans currently are under served, Executive Order 12928 (September 16, 1994) directed Federal agencies to promote procurement with."...Historically Black Colleges and Minority Institutions", and P.L. 103-327 directed the establishment of URC's at the HSI's. Executive Order 13021 (October 19, 1996) directed Federal agencies and departments to strengthen their relationships with Tribal Colleges and Universities. In response, NASA is developing a 5-year plan of action and will submit annual accomplishment reports when the White House Initiative Office for Tribal Colleges is established. Present awards to TCU's are encouraged within the five programmatic awards.

Although similar to the HBCU Program strategies, because of the differences in the evolution of minority institutions and the particularities of Federal mandates for HBCU's and Hispanic Americans, NASA's approach and implementation plan for OMUs have been adjusted to incorporate these factors. For example, the Federal mandate for Hispanic Americans directs Federal agencies to "....improve educational outcomes for Hispanic Americans participating in Federal education programs...". As a result, the Agency has placed greater emphasis on mathematics and science awards than on institutional research awards.

ACCOMPLISHMENTS AND PLANS

As a result of NASA's FY 1998 investment in OMU's, 30 OMU's were the recipient of 84 awards which reached more than 23,000 faculty, teachers and students. Specific accomplishments for each of the categories are as follows:

FY 1998 Accomplishments	University Research Centers	Institutional Research Awards	Principal Investigators	Partnership Awards
Research Population Supported:	152	165	136	45
Faculty Members	51	27	31	18
Research Associates	14	28	5	3
Postdoctoral Fellows	3	5	4	1
Bachelor-degree Level Students	44	64	54	13
Master's-degree Level Students	31	16	31	7
Doctoral-degree Level Students	9	25	11	3
Degrees Awarded:	55	17	28	7
Bachelor Degrees	25	9	15	5
Master's Degrees	26	4	11	1
Doctoral Degrees	4	4	2	1
% Socially/Economical Disadvantaged or Disabled	82%	82%	82%	86%
Research Accomplishments:				
Refereed Papers or Book Chapters:				
Published	180	106	15	8
Student (Co) Authors to above	115	62	12	15
Accepted for Publication	84	52	4	7
Student (Co) Authors to above	57	42	5	12
Technical Presentations:			48	
Total Presentations	312	139	14	23
Presentations given by Students	148	77	10	2

Leverage Achieved (in $M):				
Funding Provided by MUREP	$4.7	$4.1	$1.5	$0.7
Leverage from Other NASA Programs	$3.8	$1.0		
Leverage from Other Agencies	$6.4	$0.7	$0.4	$0.5
Technology Transfer Activities:				
Patents disclosed, applied for, or awarded	3	36	2	
Commercial products being developed or marketed	4	13	1	
Grant Awards Reporting	3	5	27	6

Three **OMU University Research Centers Awards** were established by the Headquarters Office of Space Science (OSS); Office of Aero Space Technology (OAST); Office of Space Flight (OSF); Office of Earth Science (OES), and the Office of Equal Opportunity Programs (OEOP) to achieve a broad-based, competitive aerospace research capability among the Nation's OMU's. These universities will be submitting proposals in FY 1999 that will be evaluated to determine if funding will be continued.

University	Research Focus	Enterprises	Lead NASA Installation
New Mexico	Autonomous Control Engineering	OAST	Lewis Research Center
Texas at El Paso	Pan American Center for Earth and Environmental Studies	OES	Marshall Space Flight Center
Puerto Rico at Mayagüez	Tropical Center for Earth and Space Studies	OSS, OES	Langley Research Center

OMU Institutional Research Awards (IRA) The IRA (Research) goals include: (1) strengthening and improving core research areas of significance to the NASA mission; (2) increasing the number of students who are U.S. citizens conducting space research and working in NASA-related disciplines; (3) strengthening the research environment of eligible institutions and the capability of individuals by supporting the institutional infrastructure (through the acquisition of research equipment), faculty research, disadvantaged U.S. citizens who are undergraduate and graduate student researchers; and (4) transfering technology to the market place and to minority communities. To achieve these objectives, an agency wide TRC is assigned to each of the selected IRA (Research) award recipients and are responsible for providing technical guidance. NASA promotes collaboration between its funded IRA institutions, the Centers, JPL, and with entities outside of NASA. Institutions are encouraged to seek funding through NASA's traditional opportunities, as well as other government agencies and private sources to promote future sustainability. IRA awards require substantial undergraduate and graduate student involvement in research projects.

IRA (Research)

University	Research Focus	Enterprises	Lead NASA Installation
California State-Los Angeles	The Use of Decentralized Control in Design of a Large Segmented Space Reflector	OSS	Jet Propulsion Laboratory
Florida International	High Performance Database Management with Application to Earth Sciences	OES	Goddard Space Flight Center
Puerto Rico at Rio Piedras	Land Management in the Tropics and Its Effects on the Global Environment	OES	Marshall Space Flight Center
City College of New York	Tunable Solid State Laser and Optical Imaging	OAST	Langley Research Center
New Mexico Highlands	Alliance for Nonlinear Optics	OAST	Marshall Space Flight Center

IRA (NRTS)

University	Research Focus	Enterprises	Lead NASA Installation
City College of New York	Urban Collaboration for Network Connectivity and Internet Access	OSS, OES	Goddard Space Flight Center
Texas at El Paso	Network Resources Training Sites	OSS	Goddard Space Flight Center

OMU Principal Investigator (PI) Awards

In FY 1998, funding for 7 third-year, 4 second-year and 10 new FAR awards will be provided. In FY 1999, funding for 4 third-year, 10 second-year, and 10 new FAR awards will be provided, as well as funding for individual PI awards. In FY 2000, 10 third-year, 10 second year and 10 new FAR awards will be funded.

Through the competitive process for awards, opportunities for participation in the Agency's mainstream research will expand as recipients' research capabilities are enhanced through interaction with NASA researchers and faculty. Additionally, the pool of disadvantaged students with research experience and interest in pursuing advanced degrees in the fields of science, engineering, and mathematics will increase through faculty support.

OMU Math and Science Education Awards

The Math and Science Education Awards are composed of unsolicited awards and awards made based on solicitations. Primary funding supports the following four focus areas: undergraduate awards; graduate awards; precollege awards; and teacher enhancement and preparation awards.

For the FY 1998 reporting period (Academic Year 1997-98 and Summer 1998), 132 MUREP education and training projects were conducted at OMU institutions. The institutions conducted precollege and bridge programs, education partnerships with other universities and industry, NRTS, teacher training, and graduate and undergraduate programs. These programs reached a total of 22,126 participants, predominantly at the precollege level and achieved major goals of heightening students' interest and awareness of career opportunities in MSET fields, and exposing students to the NASA mission, research and advanced technology through role models, mentors, and participation in research and other educational activities. Also in FY 1998 NASA continued a very meaningful relationship with the Hispanic Association of Colleges and Universities (HACU) through Proyecto Access, a consortium through which HACU links seven HSI's together to conduct 8-week summer programs.

During the FY 1998 reporting period, grantees reported 7,322 high school students in NASA programs and 3,510 high school students selected college preparatory MSET courses, 858 high school graduates, 582 enrolled in college, and133 selected MSET majors. There were 130 high school graduates (bridge students) in NASA programs and 54 students successfully completed their freshman year. There were 1014 teachers in teacher programs and 116 teachers received certificates. There were 2051 undergraduate students, of which 78 received undergraduate degrees; and 18 are employed in a NASA-related field. There were 74 graduate participants, 13 who received graduate degrees, and 29 employed in a NASA field. There were 19 papers published, 7 of which were authored or co-authored by students. Eighty-four students gave presentations at NASA Installations and 139 students gave presentations at national/international conferences.
In FY 1998, the five OMU MASTAP's continue to contribute to the National Education Goals by enhancing the ability of pre-service and in-service teachers to teach mathematics and science in schools under served by NASA. This has been achieved through the development of special courses, curriculums, instructional models, publications, presentation of academic papers, teacher certifications.

Pre-service teachers have gained valuable classroom experience while at the same time providing extra attention to students in schools with large numbers of disadvantaged students. In the process, several teachers completed Masters Degrees. These programs have had a positive impact on both the universities that implement them and on the school districts with which they have partnered. The program is currently being reviewed with a goal to multiply the positive results of the implemented programs. Effective and innovative instructional materials, curriculums and models developed by MASTAP programs will be distributed to a broad audience.

In FY 2000, one third year and four second year MASTAP awards will be continued. Five third year and five second year PACE awards will be continued. Ten new OMU MASTAP and/or PACE awards will be selected to replace expiring awards in FY 2000.

Additional funding of $10M was included in the FY 1999 Appropriation Bill for VA-HUD-Independent agencies for the Science, Engineering, Mathematics Aerospace Academy (SEMAA) to replicate the training provided to other sites. The three components are as follows. Living In Space for the K-4th graders has classes for both students and parents to institutionalize math and science in the home. Exploring the Solar System for 5th-8th graders increases their awareness of MSET skills and the use of laboratory equipment. Discovering Aeronautics for 9th – 12th graders was developed to be used with GRC or the Mobile Aeronautics Education Lab when available. FY 1999 funds will continue the program through FY 2000.

OMU Partnership Awards

In FY 1998, 22 Partnership Awards to OMU's in 8 states and Puerto Rico were continued. Three new Partnership Awards for the Integration of Research into Undergraduate Education (PAIR) were competitively awarded to OMU's. In FY 1999, Partnership Awards selected in FY 1997 will receive their last year funding, and the three PAIR selected for five year awards will receive second year funding. Expiring Partnership Awards will have an opportunity to competitively apply for new funding under a NASA Research Announcement. All NASA Centers and Jet Propulsion Laboratory will accept proposals, conduct the review, recommend awards for selection, and continue to manage the Partnership Awards. In FY 2000, the newly selected Partnership Award recipients will receive second year funding, the PAIR third year funding, and two new PAIR awards will be made during FY 2000.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

FISCAL YEAR 2000 ESTIMATES

GENERAL STATEMENT

GOAL STATEMENT

The Mission Support appropriation provides funding for agencywide activities which are critical to NASA's mission success. This includes funding to: support NASA's civil service workforce; to provide critical space tracking and communications capabilities required by all missions; to conduct safety and quality assurance activities; engineering policies, standards, and guidelines; advanced concept studies; and for activities to preserve NASA's core infrastructure.

STRATEGY FOR ACHIEVING GOALS

Funding included in the Mission Support appropriation supports agency-wide activities which touch all of NASA's programs:

Safety, Mission Assurance, Engineering, and Advanced Concepts: This includes funding for programs to assure the safety and quality of NASA missions, through the development, implementation and oversight of agencywide safety, reliability, maintainability and quality assurance policies and procedures. It also includes funding for engineering policies, standards, and guidelines to improve analysis tools and test methods for design and verification of spaceflight systems, and study of advanced concepts for possible future technology development and mission use.

Space Communication Services: This includes funding for the operation of the tracking, telemetry, command, data acquisition, and communications and data processing activities that are required by all NASA projects. This includes the Tracking and Data Relay Satellite System (TDRSS), and the telecommunications system which provides for real time transmission of data, video and voice information between and among NASA installations.

Research and Program Management: This includes funding for the salaries, benefits, travel requirements and other support of the civil service workforce, and the necessary funding for all of NASA's administrative functions in support of research in NASA's field centers.

Construction of Facilities: This includes funding for the repair, rehabilitation, modification and construction of the institutional facilities, the environmental compliance and restoration program, and the advanced planning of facilities and design of future facilities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

FISCAL YEAR 2000 ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1998	FY 1999	FY 2000
MISSION SUPPORT	**2380.0**	**2511.1**	**2494.9**
SAFETY, MISSION ASSURANCE, ENGINEERING, AND ADVANCED CONCEPTS	37.8	35.6	43.0
SPACE COMMUNICATION SERVICES	194.2	185.8	89.7
RESEARCH AND PROGRAM MANAGEMENT	2025.6	2121.2	2181.2
CONSTRUCTION OF FACILITIES	122.4	168.5	181.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

MISSION SUPPORT

For necessary expenses, not otherwise provided for, in carrying out mission support for human space flight programs and science, aeronautical, and technology programs, including research operations and support; space communications activities including operations, production and services; maintenance; construction of facilities including repair, rehabilitation, and modification of facilities, minor construction of new facilities and additions to existing facilities, facility planning and design, environmental compliance and restoration, and acquisition or condemnation of real property, as authorized by law; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by 5 U.S.C. 5901-5902; travel expenses; purchase, lease, charter, maintenance, and operation of mission and administrative aircraft; not to exceed $35,000 for official reception and representation expenses; and purchase (not to exceed 33 for replacement only) and hire of passenger motor vehicles; [$2,511,100,000] *$2,494,900,000*, to remain available until September 30, [2000] *2001*. *(Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.)*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISSION SUPPORT

REIMBURSABLE SUMMARY
(IN MILLIONS OF REAL YEAR DOLLARS)

	BUDGET PLAN		
	FY 1998	FY 1999	FY 2000
MISSION SUPPORT	**91.1**	**131.2**	**121.0**
SAFETY, MISSION ASSURANCE, ENGINEERING, AND ADVANCED CONCEPTS	.3	.3	.0
SPACE COMMUNICATION SERVICES	41.6	66.5	66.2
RESEARCH AND PROGRAM MANAGEMENT	47.4	58.1	52.0
CONSTRUCTION OF FACILITIES	1.8	6.3	2.8

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

DISTRIBUTION OF MISSION SUPPORT BY INSTALLATION
(Thousands of Dollars)

Program		Total	Johnson Space Center	Kennedy Space Center	Marshall Space Flight Center	Stennis Space Center	Ames Research Center	Dryden Flight Research Center	Langley Research Center	Glenn Research Center	Goddard Space Flight Center	Jet Propulsion Lab	Headquarters
Safety, Mission Assurance,	1998	37,800	5,250	750	2,095	0	6,550	200	4,135	1,465	5,600	5,823	5,932
Engineering, and	1999	35,600	7,150	735	2,500	125	5,985	435	4,250	1,310	6,030	3,130	3,950
Advanced Concepts	2000	43,000	7,100	680	1,915	235	6,099	520	4,623	1,873	8,630	7,200	4,125
Space Communication	1998	194,200	200	0	72,600	0	0	0	0	52,000	63,300	5,600	500
Services	1999	185,800	2,300	34,800	69,100	0	0	0	0	0	71,400	5,200	3,000
	2000	89,700	0	13,500	46,500	0	0	0	0	0	24,800	4,200	700
Research and Program	1998	2,025,625	332,168	230,505	282,217	40,809	166,983	54,753	214,289	192,946	327,525	0	183,430
Management	1999	2,121,200	344,130	233,050	288,860	46,840	169,150	58,420	218,170	196,500	337,240	0	228,840
	2000	2,181,200	340,600	234,500	286,300	49,700	175,100	60,900	224,400	199,900	354,000	0	255,800
Construction of Facilities	1998	118,679	4,907	17,109	23,076	8,828	5,520	6,867	7,758	14,957	14,587	12,055	3,015
	1999	165,260	13,990	28,190	31,110	10,600	13,600	4,520	10,550	17,670	18,940	13,750	2,340
	2000	175,000	15,500	30,800	25,400	11,000	12,800	6,550	9,300	18,750	17,700	9,800	17,400
Undistributed:													
Various locations	1998	3,721											
	1999	3,240											
	2000	6,000											
Total Construction of	1998	122,400											
Facilities	1999	168,500											
	2000	181,000											
TOTAL MISSION SUPPORT	1998	2,380,025	342,525	248,364	379,988	49,637	179,053	61,820	226,182	261,368	411,012	23,478	192,877
	1999	2,511,100	367,570	296,775	391,570	57,565	188,735	63,375	232,970	215,480	433,610	22,080	238,130
	2000	2,494,900	363,200	279,480	360,115	60,935	193,999	67,970	238,323	220,523	405,130	21,200	278,025

MISSION SUPPORT

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SAFETY AND MISSION ASSURANCE
OFFICE OF THE CHIEF ENGINEER
OFFICE OF THE CHIEF TECHNOLOGIST

SAFETY, MISSION ASSURANCE, ENGINEERING, AND ADVANCED CONCEPTS

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET
		(Thousands of Dollars)	
Safety and Mission Assurance	26,900	25,900	25,400
Engineering	5,900	5,300	12,900
Advanced Concepts	5,000	4,400	4,700
Total	37,800	35,600	43,000
Distribution of Program Amount by Installation			
Johnson Space Center	5,250	7,150	7,100
Kennedy Space Center	750	735	680
Marshall Space Flight Center	2,095	2,500	1,915
Stennis Space Center	--	125	235
Ames Research Center	6,550	5,985	6,099
Dryden Flight Research Center	200	435	520
Langley Research Center	4,135	4,250	4,623
Glenn Research Center	1,465	1,310	1,873
Goddard Space Flight Center	5,600	6,030	8,630
Jet Propulsion Laboratory	5,823	3,130	7,200
Headquarters	5,932	3,950	4,125
Total	37,800	35,600	43,000

Program Goals:

NASA's Safety, Mission Assurance, Engineering, and Advanced Concepts (SMAEAC) budget is an investment in the safety and success of all NASA programs. The SMAEAC budget supports the activities of the Office of Safety and Mission Assurance (OSMA), the Office of the Chief Engineer (OCE), and the Office of the Chief Technologist (OCT). These three Offices advise the Administrator, oversee NASA programs, develop Agency-wide policies and standards, and support the technology requirements of NASA flight programs.

Strategy for Achieving Goals:

OSMA ensures that sound and robust processes and supporting tools are in place throughout NASA to enable safe, successful missions. OSMA establishes NASA safety and mission assurance (SMA) strategies, policies, and standards and assures compliance. OSMA ensures that SMA disciplines are appropriately applied throughout the program life cycle. The office also provides analysis, oversight, and independent assessment (IA) of programs and flight and ground operations to ensure that suitable attention is placed on risk mitigation, that missions are conducted safely, and that there is a high probability of mission success. OSMA sponsors research, development, pilot application, and evaluation of tools, techniques, and practices that advance NASA's SMA capabilities. It also funds SMA training course development and independent assessment of the Human Exploration and Development of Space (HEDS) enterprise. Software assurance efforts develop, test, and evaluate methods to assure the performance and safety of critical flight, ground control, and robotics system software.

The OCE oversees NASA's strategic crosscutting process to "Provide Aerospace Products and Capabilities" and independently evaluates ongoing programs, proposed concepts, and options for new programs. The OCE establishes policies, standards, and technical capabilities to improve NASA engineering practices and supports evaluation and introduction of advanced electronic parts and packaging technology into NASA programs.

The OCT is NASA's principal advocate for advanced technology. As such, the OCT advises the Administrator on technology matters and develops a NASA-wide investment strategy for innovative and advanced technology. The office leads the development of NASA-wide technology goals and objectives and oversees NASA technology policies, programs, processes, and capabilities. The OCT also sponsors the NASA Institute for Advanced Concepts (NIAC), which addresses NASA strategic objectives requiring technology readiness ten to twenty years into the future.

Measures of Performance:

Metric	Description	FY 1998 Results
Mishap Prevention	Contribute to reducing the number of mishaps at NASA facilities and lessening productivity losses.	The FY 1998 lost time due to injury rate decreased 12.5% from FY 1997. NASA's rate is 1/8 that of the entire Federal government and 1/5 that of the private aerospace sector.
Safety and Quality Requirement s and Standards	Replace NASA standards with U.S. and international industry standards wherever possible. Develop and maintain NASA standards where required. Emphasize voluntary compliance and adoption of ISO 9000. Reduce cost of procuring flight and ground systems.	OSMA completed revising and reformatting all its NASA Policy Directive Documents, going from 22 documents/149 pages to 13 documents/54 pages. NPD 8730.3, "NASA Quality Management System Policy (ISO 9000)", establishing the Agency's ISO 9000 implementation requirements, and NPD 8621.1G, "NASA Mishap Reporting and Investigating Policy", were issued. Three Centers completed ISO 9000 registration.
Independent Assessments, Oversight, and Reviews	Contribute to the safety and success of NASA missions by ensuring that programs resolve all technical issues prior to flight. Evaluate adequacy of NASA safety, reliability, quality assurance, and engineering capabilities. Assess critical NASA issues, the status of development programs, and technical options for proposed programs to ensure they will reliably and effectively meet mission requirements at minimum cost.	OSMA supported four Shuttle and ten science payload launches. Technical analyses of design decisions by the International Space Station (ISS) IA help ensure future safety and on-orbit performance. The OCE completed 17 Independent Annual Reviews (IARs) of ongoing programs and six Special Assessments of spacecraft programs that resulted in improved program management processes; and established an infrastructure for collaborative engineering. Revised and initiated full implementation of NASA-wide guidelines for Program and Project Management (NPG 7120.5A)
Systems Engineering and Design Analysis	Improve and expand the use of integrated analytic methods to perform the systems engineering analyses required to define and optimize new missions and provide new and improved methods for detailed analysis and test of aerospace systems.	The OCE completed assessment of current approaches to System Engineering Metrics and Risk Management processes and developed a System Engineering Tools baseline for NASA program use. OCE improved the flexibility of the NASGRO software tool for crack growth estimation and expanded an industry-government user group to support broader external use of the tool. OCE also demonstrated capability of combined dynamic testing of spacecraft to reduce testing cost and risk of damage to flight hardware, continued development of STEP (Standard for the Exchange of Product Data) data interchange protocols for control systems, and established a test bed to demonstrate STEP applications

Metric	Description	FY 1998 Results
Engineering Standards and Practices	Improve the technical guidance available to NASA programs and integrate with commercial practice to increase commonality and interoperability through an Agency-wide standards system; accelerate adoption of voluntary consensus standards.	The OCE integrated SMA, information technology, and engineering standards into NASA-wide Preferred Technical Standards Management System and Database. The OCE completed three new NASA Standards, adopted over 400 voluntary standards, and eliminated an equal number of installation standards and requirements for Government standards while implementing Office of Management and Budget Circular A-119.
Technology Leadership Council (TLC)	Ensure NASA-wide coordination of emerging technologies critical to future missions.	Held two TLC meetings during FY 1998 to establish Agency directions and priorities. Results included assessments of NASA's management process and investment strategy for long-range critical technology and specific recommendations for meeting shortfalls and needs.
Non-Destructive Evaluation (NDE)	Develop and certify improved NDE methods for aerospace manufacturing and operations. Reduce manufacturing and test costs by reducing teardowns, scrappage, and replacements caused by destructive testing.	OSMA completed techniques for hydrogen/helium leak imaging, friction stir welding evaluation, and electronics assessment, as well as studies on probability of detection for various NDE processes
Mission Assurance	Help to "maximize the probability of success of NASA missions by using qualitative or quantitative risk assessment techniques to identify and understand the risks, take appropriate steps to control or mitigate the risks, and then accept only reasonable and appropriate levels of residual risk before proceeding with a mission" (NPD 8700.1, "NASA Policy for Safety and Mission Success," paragraph 1.b.).	OSMA incorporated new risk management policy in NPG 7120.5A. This requires program/project managers to identify, analyze, plan, track, and control risks (undesired events such as cost overrun, schedule slippage, safety mishap, or failure to achieve a needed technological breakthrough). A companion Continuous Risk Management training course was developed and piloted to 10 NASA projects; the course continues to be improved and presented throughout NASA. A Quantitative Risk Assessment System (QRAS) software application was developed and demonstrated. Its initial purpose is to evaluate the risk benefits of proposed Space Shuttle upgrades (in reducing the probability of catastrophic mishap); its long-term purpose is to assess risk for NASA missions. Risk-based assessments were conducted on major NASA programs including Shuttle-Mir, Space Flight Operations Contract, X-33, X-34, X-38, and Super Lightweight Tank. SMA conducted Prelaunch Assessment Reviews (PARs) to thoroughly understand and assess the risks leading up to launch, and established the SMA Flight Readiness Review (FRR) position for each Space Shuttle mission.

Metric	Description	FY 1998 Results
Test Effectiveness	Provide environmental test data analyses correlated against flight performance to quantify specific guidance for tailoring test programs to specific mission requirements, thus enabling lower mission development costs for better, faster, cheaper spacecraft.	OSMA completed trend analysis of Cassini Problem and Failure Reports. Developed improved pyroshock testing techniques, including guidelines for program/project test tailoring, and determined the effectiveness of random vibration testing as a workmanship screen. These efforts directly supported the Deep Space-2 program and allowed substitution of impact shock testing for random vibration qualification testing. Successfully integrated and flew the Spacecraft Loads and Acoustic Measurements instrument on the Advanced Composition Explorer (ACE)/Delta mission. Early flight data analysis indicated a conservatism (~ 10dB) in predicted and ground test levels for acoustic and random vibration signatures versus flight levels. Low frequency predictions were less conservative. The Ambient Air (versus thermal vacuum) Test program provided direct support to the Spartan 400 program: scanning electronic breadboards to locate hot spots expedited design activities and obviated the need for board-level thermal analysis.
Electronic Parts and Packaging	Qualify advanced electronic parts and packaging technologies to reduce size and power requirements for space flight systems. Facilitate use of proven components through assistance to ongoing programs and dissemination of information through parts selection databases and guidelines.	OSMA completed reliability assessment and characterization of micro-electro-mechanical systems, direct chip attachment, and compound semiconductor technology. OSMA continued radiation effects characterization of advanced emerging technologies and commercial parts, developed parts selection and utilization aids, and standardized processes for electronic parts and packaging evaluation.
Professional Development Initiative (PDI)	Develop training materials to maintain SMA skills in a changing workforce.	PDI's Web-based SMA training system transitioned to a multi-discipline, Agency-wide system, the Site for On-line Learning and Resources (SOLAR), using the PDI infrastructure. PDI Web-based users increased from 923 in FY 1997 to 1,477 in FY 1998 and formal training instances increased from 181 in FY 1997 to 324 in FY 1998. The PDI continued to develop and update instructor and Web-based courses and transition instructor-based courses to the Web where appropriate.

Accomplishments and Plans

In FY 1998, OSMA supported critical agency SMA infrastructure in order to maintain safety and mission success despite decreased Agency resources and changed business practices. Safety and mission assurance requirements specific to the new environment of "better, faster, cheaper" missions were addressed. Oversight of the Shuttle and Space Station programs was maintained. OSMA began full funding of the ISS IA effort, which supports launch readiness decisions.

New tools, techniques, and procedures, combined with process verification data and techniques that ensure process stability and capability, allowed process verification insight to replace audit-based oversight. Assurance for "better, faster, cheaper" missions moved from "rule-based" to "knowledge-based" approaches. The QRAS software application was developed for use in evaluating the risk benefits of proposed Space Shuttle upgrades. The Single Process Initiative, ISO 9000, and performance-based contracting supported acquisition reform goals of efficiency and effectiveness. OSMA supported the consolidated NASA ISO 9000 registrar contract for Center certification. The PDI provided essential, high quality instructor-based training in safety and quality assurance via the NASA Safety Training Center and the Workmanship Standards Training Centers. The PDI website infrastructure transitioned to a multi-discipline Agency system, SOLAR. The Continuous Risk Management course was piloted to ten project teams. Four Shuttle flights and ten major payload launches were supported. Shuttle Flight Operations Contract performance was evaluated.

NASA Policy Directives 8730.3, "NASA Quality Management System Policy (ISO 9000)", establishing the Agency's ISO 9000 implementation requirements, and NPD 8621.1G, "NASA Mishap Reporting and Investigating Policy", describing a consolidated policy for mishap reporting and investigating, were issued. Multiple existing NASA standards for safety and quality assurance were updated, reformatted, and reissued to conform with the Agency's new technical standard format. OSMA launched a major effort to expand the use of risk management philosophies and techniques throughout the NASA program management structure. This effort paralleled issuance of the revised NASA Policy Guidance (NPG) 7120.5A, "Program and Project Management Processes and Requirements".

The test effectiveness program and techniques for trading risk enabled informed test planning for "better, faster, cheaper" missions and improved risk management while reducing costs. Actual load, acoustic, and vibration environment measurements were made on the expendable launch vehicle for the ACE mission. Actual loads were up to 10dB less than the predictions used for design and test. Ambient air thermal testing on Spartan 400 breadboards replaced board-level thermal analysis and expedited the design. Improved pyroshock testing and random vibration workmanship screening allowed the Deep Space-2 program to eliminate random vibration qualification testing. Data on Cassini Problem and Failure Reports was correlated by cause, test type, and level of assembly.

Advanced, unique NDE techniques were developed to support less costly and longer life aerospace components. They included hydrogen/helium leak imaging, friction stir welding, electronics, and studies on probability of detection.

The Software Assurance program researched, developed, piloted, and evaluated additional standards, tools, techniques, and processes. This ongoing effort improved NASA's ability to ensure the safe and reliable performance of mission-critical software. Areas of emphasis included lifecycle risk, several safety issues, formal methods, and a reusable test bed. OSMA funding also supported operation and maintenance of the Fairmont, WV, Independent Verification and Validation (IV&V) facility.

In FY 1998, the OCE conducted 17 IARs for ongoing programs to ensure they were meeting technical and resource commitments, completed an assessment of the Mars Surveyor 2001 program, and completed six Special Assessments including the Laser Altimeter Satellite and Fastrac Engine. NPG 7120.5A revisions clarified and unified Agency-wide program/project management process requirements. A basic interactive infrastructure for Collaborative Engineering was installed in FY 1998 and is already being used to conduct real time cooperative design and analysis among NASA Centers.

In FY1998, the OCE initiated a Space Transportation Architecture Study, funded by the Office of Aerospace Technology, to assess alternatives to meeting NASA's need for human space flight through the year 2020 while achieving significant reductions in cost. When the study is completed, NASA will assess the results.

The OCE has established a unified NASA Preferred Technical Standards System to support sharing of best practices, promote interoperability of design, and to increase use of Voluntary Consensus Standards (VCS) as directed by PL104-113. Over 400 VCS were formally adopted in FY1998. Systems engineering activities completed development of a tool to integrate design requirements and verification information, and continued development of space system specific Application Protocols for ISO 10303. The tool, known as STEP - Standard for the Exchange of Product Data, is a potentially major enabling element for system-independent sharing of engineering data and distributed engineering collaboration. A combined dynamic testing task was initiated to significantly reduce structural testing requirements, both saving program dollars and lowering the risk of test damage to flight systems. Upgrading the NASGRO crack growth estimation software improved applicability to real-world situations, and a growing user group is extending use of the tool in the aerospace industry. Testing of Mars Observer pyrotechnic valves and a joint program on Advanced Airbag Technology Assessment with the Department of Transportation were completed as scheduled. Results will improve the effectiveness of future programs.

In the area of Electronic Parts and Packaging, product assurance support for "Instruments on Chip" will help lead to dramatically lighter and lower power electronics. Radiation screening for newly qualified parts and technology readiness guidelines for inserting rapidly emerging semiconductor technology into microspacecraft continued to improve mission reliability. Development of "selection tools" for commercial-off-the-shelf devices for "better, faster, cheaper" spacecraft and instruments, as well as assurance for micro-electro-mechanical devices also supported improved reliability. Results from evaluations of different vendor technologies for multi-chip modules, plastic encapsulation, micro ball-grid array packaging, direct chip attachment, analog to digital converters, active pixel arrays, and digital signal processors were disseminated via the world-wide-web. Electronic Parts and Packaging transfers from OSMA to the Office of Space Science for FY 1999.

In FY 1998, the OCE and OCT began a two-year study by the National Research Council (NRC) on Advanced Engineering Environments to assess NASA's current engineering capabilities and plans against the current best practices and projected advances in the state-of-the-art. The results of this study will be used to help guide NASA in implementing the Agency's vision for how future missions will be conceived, designed, developed and operated. A first-generation infrastructure has been established to assess the potential of available capabilities to perform distributed, collaborative engineering on current programs. The Intelligent Synthesis Environment (ISE) includes a Collaborative Engineering capability.

In FY 1998, the OCT supported a long range Agency-wide activity to revolutionize the way NASA plans, analyzes, and develops future programs. The OCT held two meetings of the Technology Leadership Council during FY 1998 to establish Agency-wide directions and priorities. The TLC serves as a forum for reviewing Agency policies, priorities, practices, and issues and coordinating the development of integrated strategic technology plans. Significant results of these meetings included assessments of NASA's management process and investment strategy for long-range critical technology with specific recommendations for meeting shortfalls and needs. In the summer of FY 1998, the OCT initiated the NASA Institute for Advanced Concepts (NIAC) through an open competitive process and selected 16 proposals. The Institute issued its first solicitation in the summer of FY 1998 for initial award by the end of the fiscal year. The NIAC concepts will complement the advanced concepts activities conducted within the NASA Enterprises. The NIAC will focus on revolutionary systems and architectural concepts that may have a major impact on future NASA missions.

In addition, the OCT developed plans to initiate the ISE program to revolutionize the way NASA develops its programs from concept through disposal, encompassing the entire program life cycle. Critical ISE activities will examine emerging technology advances in high data rate communications and networks, high performance computers, advanced human-computer interfaces, massively distributed data systems, advanced analysis methods, and the use of complex immersive environments for collaborative teaming. Ultimately, these capabilities will enable widely distributed groups of experts covering diverse areas of science, technology and engineering to work as a highly integrated, virtually co-located team.

OSMA assumes management and funding of contracted Shuttle IA efforts from the Office of Space Flight in FY 1999. The ISS IA continues to support the ISS program and OSMA flight readiness decisions. Six Shuttle and ten major payload launches will be supported. Activities to update and streamline standards and policies continue. The QRAS will be enhanced with more data and a more friendly user interface. SMA organizations will provide risk management implementation consultation, ensuring that NASA's program managers have the philosophy, tools, guidance, and expertise to make informed choices among technical, schedule, and cost risk. The PDI, as part of SOLAR, continues developing skills training modules to help maintain and improve SMA workforce skills. Significant usage increases are forecast as SOLAR provides mandatory training that was formerly instructor-based. The remaining eight NASA Centers will complete ISO 9000 certification, and the White Sands Test facility, registered in FY 1995, will undergo a tri-annual registration update.

OSMA begins an effort in human reliability to reduce risks inherent to human interaction with NASA's complex, fast-moving, high-reliability operational management systems. Tasks include standardizing close call reporting in NASA's incident reporting system, reviewing incidents for human reliability issues, and developing a human reliability training module. Test effectiveness efforts are restructured into a broader scope of failure detection and prevention. The failure prevention and detection program will increase the probability of success of NASA aeronautics and space flight projects. This will be accomplished by developing methodologies for identifying and balancing risk; providing the tools and techniques to enable projects to develop and implement effective, tailored mission assurance programs; providing the tools and techniques to enable projects to reliably infuse new technologies and heritage hardware; and integrating products into the Collaborative Engineering Environment (CEE) element of ISE. NDE efforts in X-ray imaging, pyrovalve seal evaluation, silicon carbide-based sensors, and neural-net processed holography begin; while work on methods for graphite-epoxy composites and eddy current corrosion detection continue. In the metrology and calibration area, a very low- pressure primary standard and in-place accelerometer calibration technique will be completed.

Beginning in FY 1999, operations and maintenance responsibility for the Fairmont, WV, IV&V facility resides with the Office of Aerospace Technology. This transfer completes the facility's transition to a component of the Ames Research Center. OSMA funding supports continued development of standards, tools, techniques, and processes as well as pilot application and evaluation activities. Transferring technical guidelines to software developers will help to ensure that safety and quality are built into critical software from the beginning.

In FY 1999, OCE support for IARs of ongoing programs will continue at the same level as FY1998. Six assessments are planned for FY 1999, including the Space Station Crew Return Vehicle, Next Generation Space Telescope, and New Millennium Deep Space-3. Additional Special Assessments will include a Liquid Flyback Booster Cost Assessment Study. Continued development to expand a distributed engineering infrastructure, funded under the ISE, will improve access to expertise for assessments. The NASA Space Transportation Architecture Study will be completed.

The OCE will complete adoption of currently used Voluntary Consensus Standards and accelerate replacement of NASA standards where alternatives exist. Plans include expanding standards development in cooperation with national standards organizations, completion of several new NASA standards to meet unique needs, and completing incorporation of all NASA standardization areas in the NASA Preferred Standards system. Participation in the development and negotiation of international standards for space systems and operations will continue through ISO Technical Committee 20/Subcommittee 14, Space Systems and Operations.

In systems engineering, the OCE will demonstrate analysis tools to evaluate the effect of uncertainty on system operation, extend use of the STEP data exchange standard to thermal analysis, integrated Product Data Management, and the overall systems engineering process. The OCE will implement a systems test bed to assess use of STEP for integrated product data management and transfer of multi-disciplinary design data among design centers. The initial phase of the NRC evaluation of Advanced Engineering Environments will be completed.

Space Shuttle flight validation of the force-limited vibration testing method is scheduled for May 1999. Related activities in FY1999 include development of design guidelines for advanced structural concepts including inflatable structures and integrated electronic/structural elements being considered for advanced missions.

In FY 1999 the OCT will continue to hold meetings of the TLC to assess NASA's technology development program and provide recommendations on guidelines, priorities and other ways to improve the full range of technology development activities. The NIAC will continue to fund proposals selected in response to its FY 1998 solicitation, and will issue at least one new solicitation for proposals during FY 1999. The OCT will also fund special studies and internal activities focused on specific issues relevant to the

OCT's responsibilities to assess and document Agency technology development activities, identify new technology opportunities, and guide future technology planning.

Also during FY 1999, the OCT will oversee the development of NASA's detailed plans to fully initiate the Intelligent Synthesis Environment vision in FY 2000. NASA will acquire the basic hardware and software systems to enable practical, state-of-the-art operation within a distributed, collaborative science and engineering environment. The OCT will begin establishing testbeds to guide and validate new ISE technology for NASA's specific needs. New partnerships with other government agencies and industry will leverage substantial external ISE-related investment. The OCT will begin pathfinding R&D activities to guide long-range development plans.

In FY 2000, the ISS and Shuttle IAs will support OSMA flight readiness decisions. ISS IA data will also assist the ISS program. Eight Shuttle and seven payload launches will be supported. Instructor-based SMA training courses will be converted to Web-based, and an NDE training module will be developed. System and operational safety efforts will include earthquake preparedness, voluntary hydrogen/oxygen standards, and composite overwrapped pressure vessel damage and aging issues. Operation of the Incident Reporting Information System (IRIS) and NASA Safety Reporting System (NSRS) continues. OSMA will fund Interagency Nuclear Safety Review Panel (INSRP) analysis for upcoming Mars and deep space programs that use radioactive sources.

The human reliability effort will test and implement mishap and human error countermeasures at Kennedy Space Center (KSC) in FY 2000. Modified incident reporting systems, enhancing the reporting of close-call incidents, will be operational and a human reliability Web-based training module will be on-line. Human reliability-based mishap and incident investigations and other assessments will identify the root cause of any incidents or mishaps during the intense Shuttle operations for on-orbit assembly of the International Space Station. The human reliability effort will contribute to maintaining a high level of safety in Shuttle and Space Station operations. Human reliability lessons learned will begin to be applied to NASA programs and projects outside of KSC.

Risk management efforts will continue to focus on implementation of risk management methodologies and tools by NASA programs and projects, with SMA providing expert consultation and facilitation. The Continuous Risk Management training course will be fully operational, with portions integrated into program and project management training. Each Center will have SMA staff qualified to present the course.

The tools, techniques, and results produced by the failure prevention and detection effort will enable aeronautics and space flight programs and projects to develop and implement effective, tailored mission assurance programs and reliably infuse new technologies and heritage hardware into new systems designs. Tools, techniques, and results will be integrated into the CEE.

NDE techniques for micro-electro-mechanical systems, optical and x-ray sensors, and residual structural stresses will be completed. Metrology and calibration efforts continue to develop techniques for NASA's unique measuring needs while reducing calibration costs.

Software assurance efforts will continue to develop, pilot, and evaluate tools, techniques, and processes to assure critical flight and ground software. OSMA's activity is the only effort in NASA developing software assurance capabilities.

IAR's of ongoing programs and Special Assessments of potential new programs will continue with the advantage of increased capability for use of agency-wide expertise using the collaborative engineering capabilities developed through the ISE, systems engineering and the design, analysis and test methodology program elements of the OCE program.

Emphasis will be placed on meeting NASA standardization needs through cooperative initiatives with national and international standards developers except in unique cases. Further elimination of unique Government standards will focus on harmonizing internal process standards to enhance interoperability within NASA and with commercial and international partners. Systems engineering and design analysis activities will focus on implementing priority areas highlighted by results of the National Research Council's Advanced Engineering Environments study to build capabilities needed for full implementation of the ISE. In FY 2000, the OCE will complete guidelines for combined dynamic testing and 3D nonlinear fracture analysis in structural systems, and initiate development of guidelines for integrated design methods to improve concept evaluation of new systems.

The Electronic Parts and Packaging program transfers from the Office of Space Science to OCE for FY 2000. The program will continue evaluation and risk assessment of advanced electronics. The use of qualified and characterized advanced commercial electronic components will reduce costs and shorten development times. Technology evaluations will include advanced microprocessors, microminiaturization packaging technologies, high-density electronic substrates, commercial-off-the-shelf (COTS) memories and processors, and low voltage electronics. Increased funding will support Enterprise needs to assess reliability of emerging photonics and optoelectronics, non-volatile memories, advanced passive and active components, high density electronic substrates, high density part-attach technologies, and radiation effects in low power devices and board-level technologies. These activities will provide increased functionality with less cost, accelerate the use of commercially available electronics technologies, increase attention to radiation-induced failure modes and low temperature electronics issues, and advance microminiaturization. An improved Web-based capability will efficiently support agency-wide needs for information on electronics.

In FY 2000 the OCT will continue to hold meetings of the TLC to review NASA's technology development program and provide recommendations on guidelines, priorities, and other ways to improve the full range of technology development activities. The NIAC will continue its FY 1999 studies and issue at least one new solicitation for proposals during FY 2000. The OCT will also fund special studies and internal activities focused on specific issues relevant to the OCT's responsibility to assess and document Agency technology development activities, identify new technology opportunities, and make recommendations to guide future technology planning.

In FY 2000 the OCT will oversee implementation of NASA's detailed plans to implement the ISE vision. Activities will focus on establishing R&D and application testbeds focused on NASA's specific needs to guide and validate new ISE technology. Cooperative partnerships with other government agencies and industry will leverage substantial external ISE-related investment. Long range, broad-based R&D activities will be initiated, encompassing the following: 1) advanced analysis and simulation methods, 2) life cycle integration and validation, 3) collaborative engineering, 4) intelligent computing/networking, and 5) internal/outreach activities aimed at changing NASA's overall engineering culture to embrace ISE concepts. All activities will actively involve other government agencies, industry and academia.

MISSION SUPPORT

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE FLIGHT

SPACE COMMUNICATIONS SERVICES

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
Space Network	111,700	110,300	37,800	MS 2-4
NASA Integrated Services Network	82,500	75,500	51,900	MS 2-9
[Reimbursements [non-add]]	[51,000]	[45,900]	[45,900]	
Total	194,200	185,800	89,700	
Distribution of Program Amount by Installation				
Johnson Space Center	200	2,300	--	
Marshall Space Flight Center	72,600	69,100	46,500	
Glenn Research Center	52,000	--	--	
Goddard Space Flight Center	63,300	71,400	24,800	
Jet Propulsion Laboratory	5,600	5,200	4,200	
Headquarters	500	3,000	700	
Total	194,200	185,800	89,700	

PROGRAM GOALS

The Space Communications goal is to provide high quality, reliable, and cost-effective space operations services which enable Enterprise mission execution. Reliable electronic communications are essential to the success of every NASA flight mission, from planetary spacecraft to the Space Transportation System (STS) to aeronautical flight tests.

The Space Operations Management Office (SOMO), located at the Johnson Space Center in Houston, manages the telecommunications, data processing, mission operation, and mission planning services needed to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. In line with the National Space Policy, the SOMO is committed to seeking and encouraging commercialization of NASA operations services and to participate with NASA's strategic enterprises in collaborative interagency, international, and commercial initiatives. As NASA's agent for operational communications and associated information handling services, the SOMO seeks opportunities for using technology in pursuit of more cost-effective solutions, highly optimized designs of mission systems, and advancement of NASA's and the nation's best technological and commercial interests.

The Space Communication Services segment of NASA's Space Communications program is composed of two major elements. The Space Network element provides communications support to human space flight missions and low-Earth orbital spacecraft compatible with the Tracking and Data Relay Satellite (TDRS) system and to expendable launch vehicles and research aircraft. The NASA Integrated Services Network (NISN) program element provides telecommunications interconnectivity among NASA flight support networks, project and mission control centers, data processing centers and facilities, contractor facilities, and investigator science facilities located throughout the nation and the world.

STRATEGY FOR ACHIEVING GOALS

The Space Communications program provides command, tracking and telemetry data services between the ground facilities and flight mission vehicles. The program also supports all the interconnecting telecommunications services to link tracking and data acquisition network facilities mission control facilities, data capture and processing facilities, industry and university research and laboratory facilities, and the investigating scientists. The program provides integrated solutions to operational communications and information management needs common to all NASA strategic enterprises as well as NASA-wide telecommunications network services to support all of NASA's administrative communications needs.

The range of telecommunications systems and services are provided to conduct mission operations, enable tracking, telemetry, and command of spacecraft and sub-orbital aeronautical and balloon research flights. Additionally, services and systems are provided to facilitate data capture, data processing, and data delivery for scientific analysis. The program also provides the high-speed computer networking, voice and video conferencing, fax, and other electronic mail services necessary to administer NASA programs.

These communications functions are provided through the use of space and ground-based antennas and network systems, mission control facilities, computational facilities, command management systems, data capture and telemetry processing systems, and a myriad of leased interconnecting communications systems ranging from phone lines and satellite links to optical fibers.

The program provides the necessary research and development to adapt emerging technologies to NASA communications needs. New coding and modulation techniques, antenna and transponder development, and automation applications are explored and, based on merit, demonstrated for application to future communications needs. The program also provides scheduling, network management and engineering, pre-flight communications test and verification, as well as flight system maneuver planning and analysis for selected missions. NASA's flight programs are supported through the study and coordination of data standards and communication frequencies to be used in the future. These are all parts of the strategic approach to providing the vital communications systems and services common to all NASA programs and to achieve compatibility with future commercial satellite systems an services.

Many science and exploration goals require inter-agency or international cooperation in order to be achieved. NASA Space Communications assets are provided thorough collaborative agreements to other U.S. Government agencies, commercial space enterprises, and international cooperative programs. Consistent with the National Space Policy, NASA will purchase commercially available goods and services to the fullest extent feasible, and will not conduct activities with commercial application that preclude or deter commercial space activities.

The modernization of the original White Sands Ground Terminal, along with the Second TDRSS Ground Terminal (STGT), provided fail-safe operations of the Space Network and its TDRS spacecraft. Initial planning and design of a remote ground terminal capability at Guam, extending the White Sands Ground Terminal capability by providing for coverage of the Zone of Exclusion, was completed in FY 1996. Development of the system was completed in FY 1998. The Space Network provides communications for the Space Transportation System, the Hubble Space Telescope (HST) astronomical observatory and many other NASA missions, as well as non-NASA users on a reimbursable basis. The development of the Replenishment Tracking and Data Relay Satellites is on-going. The Telecommunications program consolidated all NASA wide-area network systems in FY 1997, providing integrated services for operational and administrative communication needs at reduced costs.

Efforts are continuing to consolidate and streamline major support contract services. In FY1996, a plan to transition to a consolidated space operations contract began and has been implemented in two distinct phases. In FY 1997, two short-term, fixed-price study contracts were awarded to develop an Integrated Operations Architecture (IOA) approach to consolidate space operations activities across the Agency. On October 1, 1998, a Consolidated Space Operations Contract (CSOC) was competitively awarded to the Lockheed-Martin Space Operations Company. This contract is a 10-year, cost-plus-award-fee (CPAF) and became operational on January 1, 1999. This consolidated, integrated approach to the Space Communications program is expected to maximize space operations resources by reducing systems overlap and duplication. Significant efficiencies and economies are expected over the life of the CSOC contract. Additional efforts will be undertaken to consider other opportunities for accelerating the National Space Policy directive that NASA privatize or commercialize its space communication operations no later than 2005.

BASIS OF FY 2000 FUNDING REQUIREMENT

SPACE NETWORK

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Space Network Services	3,700	8,800	6,600
TDRS Replenishment Spacecraft	56,000	66,700	17,700
TDRS Replenishment - Launch Services	52,000	34,800	13,500
Total	111,700	110,300	37,800

PROGRAM GOALS

The Space Network program goal is to provide reliable, cost-effective space-based tracking, command and data acquisition telecommunications services to the Human space Flight program, other low-Earth-orbital science missions including observatory-class flights, and selected sub-orbital flight missions. The Space Network program provides for the implementation, maintenance, and operation of the communications systems and facilities necessary to ensure and sustain the high-quality performance of NASA flight operations systems. Replenishment Tracking and Data Relay Satellites (TDRS) and the launch systems required to deploy them are also included in this program.

The Space Network participates in collaborative interagency and international programs, and independently provides communications services to other national and commercial endeavors on a reimbursable basis.

STRATEGY FOR ACHIEVING GOALS

NASA's Space Network is comprised of a constellation of geosynchronous TDRS and associated dual ground terminals located in White Sands, New Mexico. The current TDRS constellation consists of three fully operational satellites in service (TDRS-4, 5, & 7), one fully functional satellite stored on-orbit (TDRS-6), and two partially functional spacecraft (TDRS-1 & 3). TDRS-3 is positioned over the Indian Ocean, in conjunction with a remote terminal in Guam, to increase data return from the Compton Gamma Ray Observatory (CGRO) and support Shuttle/MIR operations. TDRS-1, now in its fifteenth year, is still providing service to expendable vehicle launches and other peak loads in the eastern network node.

The Goddard Space Flight Center manages the Space Network program, including the TDRS Replenishment Spacecraft program, and the modification and/or system replacement of the ground facilities and equipment as necessary to sustain network operations for current and future missions. The Replenishment Spacecraft program providing three TDRS spacecraft under a fixed-price, commercial practices contract. The prime contract was awarded to the Hughes Space and Communications Company in 1995 and the spacecraft development has met program expectations. The first spacecraft's launch readiness is scheduled for the third quarter of CY 1999. The program provides for spacecraft compatibility modifications to the New Mexico ground terminals. Lockheed Martin Corporation is the prime contractor for launch services for the TDRS Replenishment Spacecraft.

The Lockheed Martin Space Operations Company was recently awarded the Consolidated Space Operations Contract (CSOC) on October 1, 1998, and will be the primary support service contractor responsible for systems engineering, software development and maintenance, operations, and analytical services beginning in January 1999.

The Space Network provides communication services at data rates up to 300 megabits-per-second (MBPS) using its Ku-band single-access services, data rates of up to three MBPS using its S-band, single-access services, and a low-rate service of up to 150 kilobits-per-second (KBPS) through its multiple-access service. These services provide unparalleled, flexible high-data-rate communications capabilities for flight operations of low-Earth-orbital missions. Customer satellites are provided with command, tracking, and telemetry services via the TDRS spacecraft, which act as relays for commands from and science telemetry return to the ground terminals. The ground terminals are interconnected with flight control, data capture and processing facilities responsible for mission operations.

Communications services are provided to non-NASA customers on a reimbursable basis. A large share of the Space Network Services program that provides for the operations and maintenance of the ground terminal complex is funded with the receipts from reimbursable services. This reimbursable revenue is anticipated to continue and has been taken into account in formulating the NASA FY 2000 budget request.

Space Network services provides the primary communications for orbital operations of the Space Transportation System and its attached payloads. Services are also provided to automated Earth-orbital missions which have communications systems compatible with the TDRS, and can provide nearly continuous high-data-rate services. The Space Network will provide communications services for the International Space Station (ISS) beginning in FY 1999. Services will also be provided on an agreed-to basis to NASA's International partners. Agreements are in place with Japan, the European Space Agency, and Canada. Negotiations are continuing with the Russian Space Agency as a participant for potential cooperative endeavors in telecommunications.

In addition to the day-to-day operations of the Space Network satellites and ground terminals, the program provides for the replenishment of the satellite assets.

SCHEDULE AND OUTPUTS

	FY 1998		FY 1999		FY 2000
	Plan	Actual	Plan	Current	Plan
Number of hours of network service (thousands)	60,000	44,300	78,000	54,100	62,000
Number of Space Shuttle Luanches supported	6	4	8	7	8
Number of NASA.Other ELV Launches supported	23	23	20	20	25

The projected output of network services remained relatively level through FY 1998. The initiation of the ISS assembly, and the launch of Earth Observation System (EOS) AM-1 and Landsat-7 will necessitate an increased level of communication services in FY 1999. In FY 2000, full-up support to the ISS will necessitate further increases in the level of communication services.

TDRS Replenishment Spacecraft

Start Integration and Test for TDRS-I Plan: April 1998 Actual: May 1998	Start of spacecraft assembly, as well as electrical, environmental, and performance testing. The process begins with spacecraft-level assembly and test. The start of TDRS I integration and test process was delayed due to efforts expended on additional TDRS H development activities. There is no impact on the TDRS I flight readiness dates.
Start Integration and Test for TDRS-J Plan: June 1998 Actual: September 1998	Start of spacecraft assembly, as well as electrical, environmental, and performance testing. The process begins with spacecraft-level assembly and test. The start of TDRS J integration and test process was delayed due to efforts expended on additional TDRS H development activities. There is no impact on the TDRS J flight readiness dates.
Pre-Environmental Review for TDRS-H Plan: July 1998 Actual: November 1998	Verification that the spacecraft is ready for system level environmental testing. Pre-environmental reviews were rephased due to a number of unit level problems on TDRS H, the uniqueness of the TDRS-H payload, and the first-time use of electronic ground test software on TDRS H.
Pre-Environmental Review for TDRS-I Plan: October 1998 Revised: March 1999	Verification that the spacecraft is ready for system level environmental testing. Pre-environmental reviews were rephased due to a number of unit level problems on TDRS H, the uniqueness of the TDRS-H payload, and the first-time use of electronic ground test software on TDRS H.
Pre-Environmental Review for TDRS-J Plan: February 1999 Revised: May 1999	Verification that the spacecraft is ready for system level environmental testing. Pre-environmental reviews were rephased due to a number of unit level problems on TDRS H, the uniqueness of the TDRS-H payload, and the first-time use of electronic ground test software on TDRS H.
Complete Integration and Test - TDRS-H Plan: January 1999 Revised: April 1999	Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch.
Complete Integration and Test – TDRS-I Plan: May 1999 Revised: June 1999	Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch.

Complete Integration and Test - TDRS-J Plan: September 1999 Revised: August 1999	Completion of spacecraft performance and environmental tests allows final assembly and re-testing to begin prior to shipment for launch.
Launch TDRS-H Plan: 4rd Qtr FY 1999	Launch within four years of contract award will be performed, ensuring the continuity of TDRSS services to user space flight systems. Launch of TDRS-I and TDRS-J is now scheduled for 2002 and 2003.

CONSOLIDATED SPACE OPERATIONS CONTRACT (CSOC)

Phase 1 Contract Award	May 1997
Phase 2 Proposal due	January 1998
Phase 2 Contract Award	October 1998
Phase 2 Phase-In	October-December 1998
Phase 2 CSOC In Force	January 1999

ACCOMPLISHMENTS AND PLANS

The Space Network is required to operate 24 hours per day, 7 days per week, providing data relay services to many flight missions. In FY 1998, the missions supported included four Space Shuttle flights and their attached payloads, observatory-class spacecraft in low-Earth orbit such as Hubble Space Telescope (HST) and the Compton Gamma Ray Observatory(CGRO), as well as other compatible missions such as Ocean Topography Experiment, Extreme Ultraviolet Explorer (EUVE), Department of Defense customers, the Rossi X-ray Timing Explorer (RXTE), the Starlink research aircraft, Engineering Test Satellite(ETS-VII), Tropical Rainfall Measurement Mission(TRMM), and the Long Duration Balloon program. The Space Network extended service (on a reimbursable basis) to the expendable launch vehicle community including agreements with US Air Force Titan and Lockheed Martin's commercial Atlas programs.

In FY 1999, the Space Network will continue to provide services to the Space Shuttle Flights and their attached payloads as well as the construction phase of the International Space Station, LANDSAT-7, and the Earth Observing System AM-1 mission.

Efforts began on the establishment of a more robust remote terminal capable of full service provision to users in the TDRS zone of exclusion. The implementation of a full service remote terminal on Guam began with the approved FY 1995 Operating Plan reprogramming action late in FY 1996. The Guam Remote Ground Terminal (GRGT) development was implemented with site development at a U.S. Navy location in Guam. The GRGT extends the capability of the White Sands Ground Terminals to provide full service coverage in the former Zone of Exclusion. This terminal became operational in mid-FY 1998 and replaced the less capable terminal located in Australia. This remote terminal has already proven invaluable in boosting the scientific return from the Compton Gamma Ray Observatory.

Preliminary engineering studies were initiated to add Demand Access capability that would allow customers to directly obtain services from the Space Network without scheduling. Demand access will be installed at White Sands and available for customer use in mid-FY 1999.

During FY 1998, development activities for the TDRS Replenishment Spacecraft continued to progress, with spacecraft manufacturing continuing and integration and test beginning. Modifications to the White Sands Complex ground support continued. Integration activities associated with TDRS-I and J were initiated. The TDRS-I and J Atlas IIA launch services options were exercised on July 1, 1998. In FY 1999, integration activities associated with TDRS-H will be completed and the spacecraft will be launched in late FY 1999. TDRS-I and J spacecraft manufacturing, integration, and testing activities will continue. Modifications and testing of TDRS-H, I, J ground systems will be completed at the White Sands Complex in preparation for TDRS-H on-orbit support. In FY 2000, on-orbit testing and acceptance of the TDRS-H spacecraft will be completed. Modifications to the ground terminal will undergo final acceptance. The TDRS-I and J spacecraft will have completed integration and testing activities and will be available for launch.

BASIS OF FY 2000 FUNDING REQUIREMENT

NASA INTEGRATED SERVICES NETWORK (NISN)

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
NASA Integrated Services Network....................................	82,500	75,500	51,900

PROGRAM GOALS

The NASA Integrated Services Network (NISN) goal is to provide high-quality, reliable, cost-effective telecommunications systems and services for mission control, science data handling, and program administration for NASA programs. The NISN program provides for the implementation, maintenance, and operation of the telecommunications services, control centers, switching systems, and other equipment necessary to provide an integrated approach to NASA communication requirements.

The NISN supports NASA's programs in collaborative interagency, international, and commercial enterprises. Many collaborative arrangements are performed on a reimbursable basis.

STRATEGY FOR ACHIEVING GOALS

NISN is a nationwide system of leased voice, video, and data services; leased wide-band terrestrial and satellite circuits; and control centers, switching centers, network equipment and other communications devices. International telecommunications links are also provided to NASA's Deep Space Network (DSN) sites in Australia and Spain; Spaceflight Tracking and Data Network (STDN) sites outside the Continental U.S.; and common telecommunications exchange points that provide interconnectivity to NASA international partners. Administrative, scientific, and mission control exchanges among NASA and its industrial and scientific partners are supported by NISN networks and systems. Support and participation by other U.S. agencies, universities, and research centers, and by other space-faring nations, are also facilitated, including the provision of secure circuits, systems, and facilities. Domestic Telecommunications circuits are primarily leased by NASA under the FTS-2000 contract managed by the General Services Administration; international circuits are leased under separate contractual arrangements. NISN maintains cooperative networking agreements for exchanging services with the European Space Agency (ESA), Canada, Japan, France, and Russia. The Computer Science Corporation and AlliedSignal Technical Services Corporation provide engineering and operations support for the NISN.

The NISN is managed by the NISN Project Office at the Marshall Space Flight Center in partnership with the Goddard Space Flight Center. NISN provides unique mission and mission support telecommunications services to all NASA Centers supporting contractor locations, international partners, research institutes, and universities. NASA also provides telecommunications services to non-NASA customers on a reimbursable basis.

Command, telemetry, and voice systems communications are provided between spacecraft mission control facilities, tracking and data acquisition networks, launch sites, NASA data processing centers, and scientific investigators whose support is critical to mission control and command. NISN support NASA aeronautical test sites, as well as preflight verification of NASA spacecraft systems and their interconnectivity with NASA communications systems.

The NISN interconnects NASA installations and national and international aerospace contractors, laboratories, scientific investigators, educational institutions, and other Government installations in support of administrative, science data exchange, and other research and analysis activities. Specific mission support services provided by the NISN are voice and video teleconferencing, broadcast television, computer networking services, as well as data handling and transfer services including Internet connectivity.

NISN provides for the improvement, operation and maintenance of NASA network systems and facilities. Telecommunications network systems include digital voice, data and video switching equipment, audio and video conferencing and bridging systems, wide-band multiplexing equipment, and sophisticated network management, monitoring, and fault isolation systems. Equipment and facilities of NASA Select Television are also provided by the NISN.

Telecommunications services are rapidly developing and maturing. With the advancements of telecommunications technology and standards, NASA telecommunications services are now more readily available from commercial sources. NISN continually analyzes current telecommunications requirements to determine the feasibility of providing NASA telecommunications services through commercial sources. NISN also maintains a close relationship with the NASA Research and Education Network (NREN), NASA's research and development, to determine what information technologies are beneficial to support NASA's growing telecommunications needs. As technologies become standard and commercially available, NISN conducts study and cost analyses to determine the feasibility of purchasing these services for use by the NASA community.

SCHEDULE AND OUTPUTS

	FY 1998 Plan	Actual	FY 1999 Plan	Current	FY 2000 Plan
Number of locations connected	400	398	450	410	420
Number of electronic conferences	31,500	41,000	34,500	45,000	48,000

Constrained travel budgets continue to increase the number of electronic conferences supported within NASA. As more program and administrative services, such as the Consolidated SuperComputer Management and Integrated Financial Management Programs, are consolidated to one center, reliance on the networking services increases. Users no longer have "center" resources, but are accessing consolidated Agency resources across the NISN network. This has resulted in increased network connections.

ACCOMPLISHMENTS AND PLANS

In FY 1998, NISN completed the implementation activities for the commercialization of the Video Teleconferencing Service, the Voice Teleconferencing Service, the Facsimile Broadcast service, and the transmission for mission support routed data services. These services provide support to all NASA programs and Centers.

NISN completed the transition of the NISN Video Teleconferencing Service to the General Services Administration's Federal Telecommunications Services (FTS) 2000 Switched Compressed Video Transmission Service (SCVTS). This video service is shared by several government agencies, provides connectivity to commercial video services such as those provided by Sprint and MCI, and is also compatible to desktop video systems. This transition standardizes NASA video teleconferencing service on the industry standard of voice activated switching, and provides greater access to non-NASA video systems.

NISN established a "meet-me" type voice teleconferencing system, based on a commercially provided service from MCI. This service enhances NISN existing reservation voice teleconferencing service and allows users to participate in voice teleconferences from locations other than their offices and at their convenience.

NISN replaced the existing FaxXchange service, which consisted of dedicated hardware providing broadcast fax distribution, with a commercially provided service from MCI. The MCI service provided for a more reliable service, additional features, and usage based pricing that would not have been available on the FaxXchange service without extensive and costly upgrades.

NISN completed the transition of its transmission infrastructure for mission support routed data services to an Asynchronous Transfer Mode (ATM) infrastructure, provided by FTS2000 Network B vendor- Sprint. NISN has also expanded the use of this network from the originally planned eight locations to ten NASA locations. NISN and NASA Research and Education Network (NREN) continue to share these services, resulting in lower network infrastructure costs for NASA as a whole. In addition to commercialization of the transmission, NISN began several studies to strengthen its peering relationships at common network access points, such as the Chicago Network Access Point (NAP) and the Sprint NAP. These are in addition to existing connectivity to internet exchange points on both the west and east coast. These additional connections have increased NISN's access to other government and education locations. NISN is also participating in the development of the Next Generation Internet Exchange (NGIX) sites in conjunction with the Department of Defense, Department of Energy, and the industry provided Abilene network. This will allow network connectivity to many NASA partners without the installation of dedicated services. These peering relationships will greatly benefit the distribution of the Earth Observing System (EOS) data as well as provide connectivity to many of the ISS principle investigators.

NISN completed the implementation of the Mission IP service. Through the use of conversion devices, the 4800 Bit Block data from spacecraft is converted to the industry standard Internet protocol (IP). This allowed the use of standard network implementation to support mission services. Testing of this service was completed during multiple Space Shuttle Missions and has been accepted by the user community for primary support of NASA missions.

NISN participated in the development of the Guam Remote Ground Terminal (GRGT), which was dedicated in July 1998. NISN provided the network connectivity, to support voice and data services, from White Sands to Guam. Extensive planning and service testing, in conjunction with other responsible areas of the development of the GRGT, was supported.

NISN participated in a team effort to enhance the general Internet connectivity from the South Pole. The South Pole TDRSS Relay (SPTR) System allowed users in the South Pole to augment their commercial internet service, provided through the GOES-3 and LES-9 satellites, with service via NASA's TDRSS satellite. The TDRSS service provided up to two and half hours additional visibility from the South Pole as well as increased network access to accommodate the large imaging data file transfers. NISN provided the network connectivity from White Sands to the general Internet and also ensured proper routing between the two connection methods. The SPTR effort was conducted in partnership with the National Science Foundation and supports the Science and Technology Center for Astrophysical Research in Antarctica (CARA) and the Antarctic Muon and Neutrino Detector Array (AMANDA). CARA and AMANDA provide observatories at the South Pole with instrumentation designed to probe the outer reaches of the universe.

NISN continued its participation in industry forums with presentations on ATM addressing to the Next Generation Internet (NGI)'s Joint Engineering Team, ATM Switched Virtual Channels at the ATM98 Conference, and Quality of Service (QoS) Development at the NREN Workshop. These activities keep NISN in the forefront of technology developments in the industry and across the government agencies. In addition to these activities, NISN also completed the downsizing of the NASA Packet Switching System (NPSS), a legacy X.25 network. Customer applications have been transitioned to other NISN services. The network continues to be used to support management of network resources. NISN has conducted a complete study of all network resources, including commercially provided services to ensure Year 2000 (Y2K) compliance. NISN has developed schedules and implementation plans to complete necessary changes by December 1998. NISN also completed the implementation of additional capacity and services to the Russian telecommunications infrastructure in order to support the Phase II International Space Station requirements. These services included additional video teleconferencing, routed data, and local area connectivity to the Moscow Mission Control Center and the Gagarin Cosmonaut Training Center.

In FY 1999, NISN will complete the necessary changes for the network resources to be Y2K compliant in December 1998. This will support NASA's goal to be Y2K compliant by February 1999. NISN will continue to support the development of the NGIXs, which will increase NISN's ability to provide enhanced-routed data services to NISN customers such as ISS and EOS. NISN will continue to play an active role in technology assessments, focusing on voice over ATM and IP, QoS prototyping, and routing protocol evaluation. NISN will add additional capacity, network connections, and services as necessary to support the initial implementation of the IFMP, and the growth of the ISS and EOS programs. NISN will complete the migration of services to the new Consolidation Space Operations Contract (CSOC) and the Federal Telecommunications Services - 2001 (FTS2001) contracts.

In FY2000, NISN will continue to analyze commercial services for potential use in meeting NASA's expanding Mission Requirements. NASA will be adding services in support continued implementation of IFMP, CoSMO, ISS Phase II, National Oceanic and Atmospheric Administration (NOAA)-K, Earth Observation System, Advanced Composition Explorer (ACE), Advanced Earth Observing Satellite (ADEOS) and TRMM.

MISSION SUPPORT

FY 2000 ESTIMATES

RESEARCH AND PROGRAM MANAGEMENT

PROGRAM GOALS

To acquire and maintain a civil service workforce which reflects the cultural diversity of the Nation, which is properly sized and which possesses the right set of human resource skills in the right locations to accomplish NASA's research, development, and operational missions with innovation, excellence, and efficiency.

STRATEGY FOR ACHIEVING GOALS

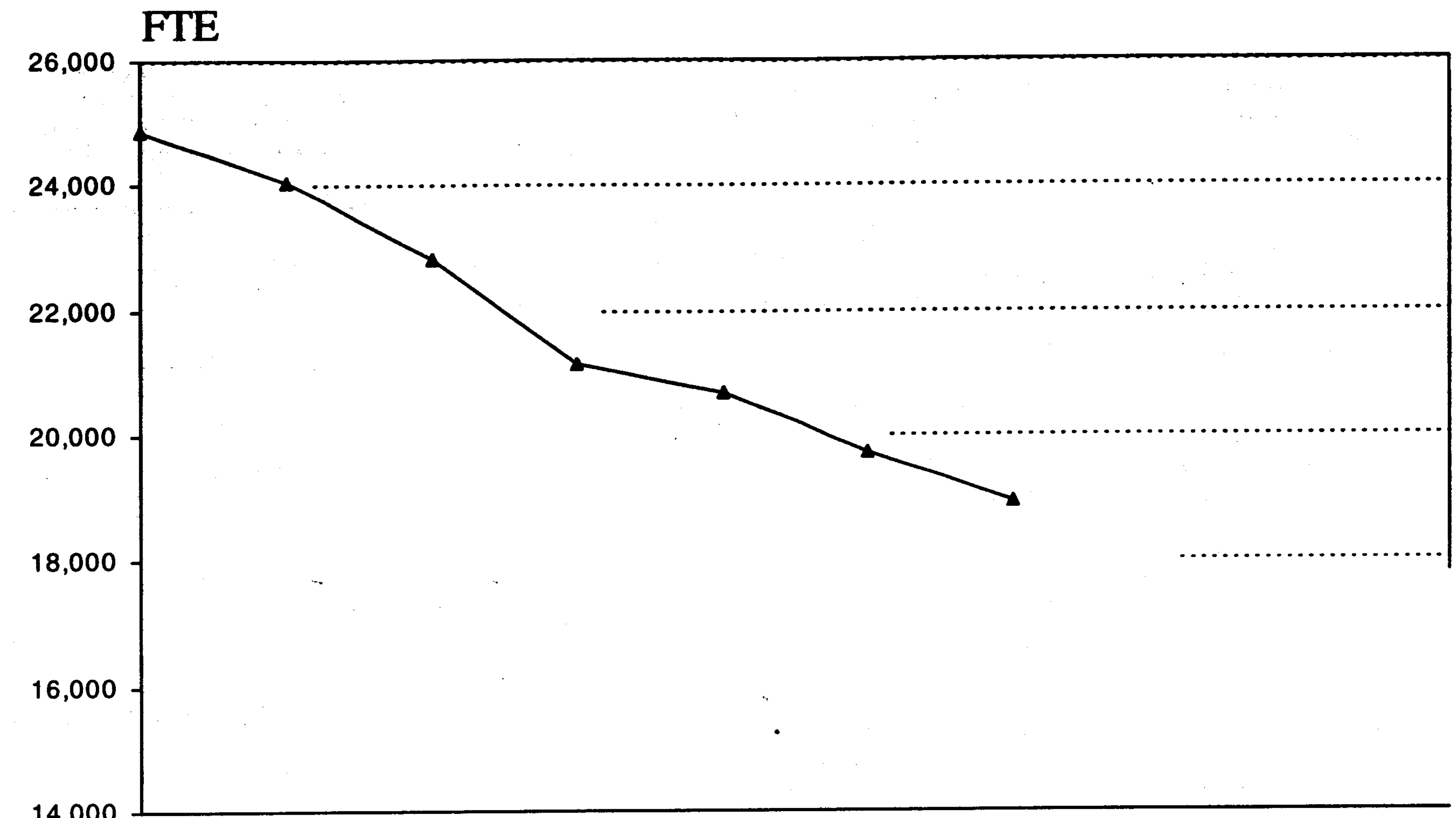
This civil service workforce is the underpinning for the successful accomplishment of the Nation's civil aeronautics and space programs. These are the people who plan the programs; conduct and oversee the research; select and monitor the contractors; manage the various research, development, and test activities; and oversee all of NASA's operations. A key dimension of the reinvention of NASA has been the restructuring of the civil service workforce to deliver a space and aeronautics program that is balanced, relevant, and at the forefront of technology development. By the end of FY 2000, NASA plans to have restructured the size and composition of the workforce to fewer than 18,000 civil servants, nearly a 30 percent reduction from the authorized FY 1992 levels of just over 25,000. Despite the fact that such reductions far exceed expected natural attrition; the Agency will achieve these reductions without resorting to a disruptive reduction in force. The primary strategies involved include reduced, extensive but managed use of the Agency's buyout authority, geographic relocations, and the provision of outplacement services.

The Research and Program Management (R&PM) program provides the salaries, other personnel and related costs, travel and the necessary support for all of NASA's administrative functions and other basic services in support of research and development activities at NASA Installations. The salaries, benefits, and supporting costs of this workforce comprise approximately 75% of the requested funding. Administrative and other support is 23% of the request. The remaining 2% of the request is required to fund travel necessary to manage NASA and its programs.

ACCOMPLISHMENTS AND PLANS

Once again NASA has achieved the full-time equivalent (FTE) targets included in the NASA Workforce Restructuring plan for FY 1998 ahead of schedule. The Agency continued to make progress towards specific workforce goals established by the National Performance Review (NPR). These goals were met ahead of schedule through the implementation of a restrictive hiring policy and the buyout conducted in FY 1998. The successful buyout used early in FY 1998 resulted in more than double the normal annual attrition. As a result, the Agency used only 18,924 FTE compared to its original plan of 19,364. A particularly noteworthy achievement is the completion of the reduction to the infrastructure at Headquarters through the

NASA FTE Civil Service Reduction Plan



	FY 93	FY 94	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01
FTE Limit	24,731	23,623	23,075	21,555	20,501	19,364	18,545	17,970	17,783

Does not include the NASA Office of Inspector General aggressive redeployment of Headquarters personnel to the Field Installations and losses through attrition. As a result, the Agency has reached the NPR goal of a reduction by 50% at Headquarters more than 4 years ahead of schedule, and did it without resorting to a reduction in force. At the Field Installations, operational activities continue to be transferred to commercial operators or to other Federal agencies where feasible. Civilian employment at the end of FY 1997 was about 18,650, a reduction of about 6,400 or 25% since 1993.

The Agency also successfully met the other goals for FY 1998 established as part of the NPR:

- The supervisory span of control has gone from 1:5 in FY 1993 to 1:10 in FY 1998.
- Targeted administrative staffs have declined more than 29% from FY 1993 levels.
- Headquarters employment has been reduced by more than 1,140 or 55% from FY 1993.

The NASA workforce target for FY 2000 is still fewer than 18,000 FTE. Achieving the remaining reduction of more than 1,000 civil servants from the FY 1998 level represents a formidable objective. NASA has stressed, and will continue to stress, the need to minimize adverse impacts on the workforce. The plan is to aggressively use all available voluntary approaches to reductions for as long as possible before employing involuntary methods.

The remaining reduction in FTE is concentrated in only three of NASA's ten Centers. Central to this strategy in FY 1999 and FY 2000 is once again implementation of an aggressive buyout plan at three of the Office of Space Flight Centers to double the number of losses expected under the normal attrition. These NASA Centers that still need to reduce, have structured their buyout planning based on the results of comprehensive workforce assessments and their Workforce 2000 strategic plans. These plans identify the Center of Excellence and Mission for the Center, its restructuring strategy, and the number and skill mix of positions required for FY 2000. Those Centers have focused their plans for the buyout at their site based on consideration of what types of positions would be in excess in the future. The other seven Centers have reached the targets associated with the strategic plan, Centers of Excellence, and Lead Center roles defined over the past several years. This budget allows these Centers to begin the gradual replenishment and rebalancing of skills drained during the severe hiring constraints of the last 5 years. The Agency approach, as well as a summary by Center, is included in the Agency's workforce restructuring plan, which will be submitted to Congress with this budget.

The FY 2000 budget estimate of $2,181.2 million for Research and Program Management represents a continuation of the of the aggressive downsizing NASA has undertaken since FY 1993 and incorporates the estimated reduction associated with the planned FY 1999 and FY 2000 buyouts. The requested funding level for FY 2000 is an increase of $60.0 million from the FY 1999 budget plan of $2,121.2 million. Of this total increase, funding for Research and Operations Support increased $13.0 million. This increase reflects an augmentation to the Headquarters Operations budget. Included are increases for the CIO Initiatives, IFMP, and day to day operations such as parking, printing and graphics, and projected rent increases. Funding for Travel increases by $2.9 million to accommodate rapidly accelerating costs of travel both domestic and international primarily associated with Space Station and other program initiatives across the Agency.

Personnel and related costs increase by $44.1 million from FY 1999 to FY 2000. These increases fully fund the civil service workforce, the full year cost of the FY 1999 pay raise, the pay raise projected to be effective in January 2000, and normal salary growth offset by a 575 FTE reduction.

In summary, the FY 2000 budget requirement of $2,181,200,000 will provide for 17,970 FTE civil service workyears to support the activities at nine NASA Installations and Headquarters.

The following describes, in detail, the cost elements within this program.

I. Personnel and Related Costs

A. Compensation and Benefits

1. Compensation

a. Permanent Positions: This part of Personnel and Related Costs covers the salaries of the full-time permanent civil service workforce and is the largest portion of this functional category.

b. Other Than Full-Time Permanent Positions: This category includes the salaries of NASA's non-permanent workforce. Programs such as Presidential Management Interns, students participating in cooperative training, summer employment, youth opportunity, and temporary clerical support are covered in this category.

c. Reimbursable Detailees: In accordance with existing agreements, NASA reimburses the parent Federal organization for the salaries and related costs of persons detailed to NASA.

d. Overtime and Other Compensation: Overtime, holiday, post and night differential, and hazardous duty pay are included in this category. Also included are incentive awards for outstanding achievement and superior performance.

2. Benefits: In addition to compensation, NASA, as authorized and required by law, makes the employer's contribution to personnel benefits. These benefits include contributions to the Civil Service Retirement Fund, the Federal Employees Retirement System, employees' life and health insurance, payments to the Medicare fund for permanent employees, and social security contributions. Payments to the civil service retirement fund for re-employed annuitants and severance pay to former employees involuntarily separated through no fault of their own are also included.

B. Supporting Costs

1. Transfer of Personnel: Provided under this category are relocation costs required by law, such as the expenses of selling and buying a home, subsistence expenses, and the movement and storage of household goods.

2. Investigative Services: The Office of Personnel Management is reimbursed for activities such as security investigations of new hires and revalidation of sensitive position clearances, recruitment advertising, and Federal wage system surveys.

3. Personnel Training: Training is provided within the framework of the Government Employees Training Act of 1958. Part of the training costs is for courses offered by other Government agencies, and the remainder is for training through nongovernment sources.

II. Travel

A. Program Travel: The largest part of travel is for direction, coordination, and management of program activities including international programs and activities. The complexity of the programs and the geographical distribution of NASA Installations and contractors necessitate this category of travel. As projects reach the flight stage, support is required for prelaunch activities including overseas travel to launch and tracking sites. The amount of travel required for flight projects is significant as it is directly related to the number of systems and subsystems, the number of design reviews, and the number and complexity of the launches and associated ground operations.

B. Scientific and Technical Development Travel: Travel to scientific and technical meetings and seminars permits employees engaged in research and development to participate in both Government sponsored and nongovernment sponsored activities. This participation allows personnel to benefit from exposure to technological advances, which arise outside NASA, as well as allowing personnel to present both accomplishments and problems to their associates and provides for the dissemination of technical results to the United States community.

C. Management and Operations Travel: Management and operations travel provides for the direction and coordination of general management matters and travel by officials to review the status of programs. It also includes travel by functional managers in such areas as personnel, financial management, and procurement. This category also includes the cost of travel of unpaid members of research advisory committees; and initial duty station, permanent change of assignment, and related travel expenses.

III. Research Operations Support

A. Facilities Services: Facilities Services provides basic security, fire protection, and other custodial services. It also provides maintenance of roads and grounds and of all administrative buildings and facilities. Finally, it provides rental of administrative buildings and all utility costs of administrative buildings.

B. Technical Services: Technical Services provides the Administrative Automatic Data Processing capability that supports Accounting, Payroll, Budgeting, Procurement, and Personnel as well as all the other Administrative functions. It also funds the Graphics and Photographic support to these functions. Finally, it funds the Installationwide safety and public information programs.

C. Management and Operations: Management and Operations funds the telephone, mail, and logistics systems, the administrative equipment and supplies, and the transportation system including the general purpose motor pools and the program support aircraft. It also funds the basic medical and environmental health programs. Finally, it funds printing and reproduction and all other support, such as small contract and purchases for the Center Directors staff and the Administrative functions.

SUMMARY OF BUDGET PLAN BY FUNCTION

	FY 1998 OPLAN 9/29/99	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET
PERSONNEL AND RELATED COSTS	$1,592.3	$1,602.8	$1,646.9
TRAVEL	$44.4	$48.8	$51.7
RESEARCH OPERATIONS SUPPORT	$388.9	$469.6	$482.6
TOTAL PROGRAM PLAN	$2,025.6	$2,121.2	$2,181.2

DETAIL OF BUDGET PLAN BY FUNCTION

	FY 1998	FY 1999	FY 2000
		(Millions of Dollars)	
I. Personnel and related costs	$1,592.3	$1,602.8	$1,646.9
A. Compensation and benefits	$1,540.7	$1,557.9	$1,598.1
1. Compensation	$1,255.9	$1,282.3	$1,320.9
2. Benefits	$284.8	$275.6	$277.2
B. Supporting costs	$51.6	$44.9	$48.8
1. Transfer of personnel	$12.0	$10.7	$9.5
2. Investigative services	$2.5	$1.5	$1.7
3. Personnel training	$37.1	$32.7	$37.6
II. Travel	$44.4	$48.8	$51.7
A. Program travel	$28.0	$30.4	$32.5
B. Scientific and technical development travel	$5.1	$5.4	$5.7
C. Management and operations travel	$11.3	$13.0	$13.5
III. Research operations support	$388.9	$469.6	$482.6
A. Facilities services	$124.1	$127.3	$130.5
B. Technical services	$147.2	$189.3	$206.5
C. Management and operations	$117.6	$153.0	$145.6
Total	$2,025.6	$2,121.2	$2,181.2

DISTRIBUTION OF BUDGET PLAN BY FUNCTION BY INSTALLATION (MILLIONS OF DOLLARS)

FUNCTION	TOTAL NASA	JSC	KSC	MSFC	SSC	GSFC	ARC	DFRC	LARC	GRC	HQS
PERSONNEL AND RELATED COSTS											
FY 1998	1,592.3	284.0	154.0	229.2	18.9	270.8	135.2	44.7	188.0	164.9	102.6
FY 1999	1,602.8	287.1	149.7	227.6	20.5	276.3	135.9	49.9	188.3	165.0	102.5
FY 2000	1,646.9	287.5	149.2	227.0	21.3	289.3	142.4	53.3	199.6	171.3	106.0
TRAVEL											
FY 1998	44.4	8.1	4.0	6.1	0.6	6.8	3.5	1.5	4.0	3.4	6.4
FY 1999	48.8	8.8	5.0	6.4	0.6	7.5	3.3	1.4	4.9	3.7	7.1
FY 2000	51.7	9.4	5.4	6.6	0.8	8.1	3.8	1.5	4.8	3.9	7.4
RESEARCH OPERATIONS SUPPORT											
FY 1998	388.9	40.1	72.5	46.9	21.3	49.9	28.3	8.6	22.3	24.6	74.4
FY 1999	469.6	48.2	78.4	54.9	25.7	53.4	29.9	7.1	25.0	27.8	119.2
FY 2000	482.6	43.7	79.9	52.7	27.6	56.6	28.9	6.1	20.0	24.7	142.4
TOTAL											
FY 1998	2,025.6	332.2	230.5	282.2	40.8	327.5	167.0	54.8	214.3	192.9	183.4
FY 1999	2,121.2	344.1	233.1	288.9	46.8	337.2	169.1	58.4	218.2	196.5	228.8
FY 2000	2,181.2	340.6	234.5	286.3	49.7	354.0	175.1	60.9	224.4	199.9	255.8

SUMMARY OF BUDGET PLAN BY INSTALLATION
(MILLIONS OF DOLLARS)

	FY 1998	FY 1999	FY 2000
JOHNSON SPACE CENTER	$332.2	$344.1	$340.6
KENNEDY SPACE CENTER	$230.5	$233.1	$234.5
MARSHALL SPACE FLIGHT CENTER	$282.2	$288.9	$286.3
STENNIS SPACE CENTER	$40.8	$46.8	$49.7
AMES RESEARCH CENTER	$167.0	$169.1	$175.1
DRYDEN FLIGHT RESEARCH CENTER	$54.8	$58.4	$60.9
LANGLEY RESEARCH CENTER	$214.3	$218.2	$224.4
GLENN RESEARCH CENTER	$192.9	$196.5	$199.9
GODDARD SPACE FLIGHT CENTER	$327.5	$337.2	$354.0
HEADQUARTERS	$183.4	$228.8	$255.8
AGENCY TOTAL	$2,025.6	$2,121.2	$2,181.2

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY INSTALLATION

	FY 1998	FY 1999	FY 2000
Johnson Space Center	3,147	2,992	2,819
Kennedy Space Center	1,869	1,784	1,633
Marshall Space Flight Center	2,822	2,690	2,525
Stennis Space Center	244	260	260
Goddard Space Flight Center	3,338	3,351	3,304
Ames Research Center	1,478	1,457	1,457
Dryden Flight Research Center	558	636	634
Langley Research Center	2,420	2,389	2,374
Glenn Research Center	2,074	2,003	1,983
Headquarters	974	983	981
Total, full-time equivalents	18,924	18,545	17,970

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

	FY 1998	FY 1999	FY 2000
Space station	2,172	2,560	2,575
U.S./Russian cooperative program	32	27	15
Space shuttle	2,341	2,172	2,043
Payload and utilization operations	533	324	306
Space science	1,871	1,865	1,787
Life and microgravity sciences	601	529	512
Earth Science	1,560	1,496	1,518
Aero-space technology	3,235	3,126	3,018
Advanced space transportation technology	1,078	1,037	1,094
Commercial technology programs	181	159	157
Academic programs	37	35	33
Mission communication services	296	283	223
Space communications services	91	108	93
Safety, reliability and quality assurance	128	110	102
Construction of facilities	120	128	123
Subtotal, direct full-time equivalents	14,276	13,959	13,599
Program management (Headquarters)	47	46	44
Center management and operations	4,601	4,540	4,327
Total, full-time equivalents	18,924	18,545	17,970

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

LYNDON B. JOHNSON SPACE CENTER

ROLES AND MISSIONS

SPACE STATION – Development of the International Space Station will provide an on-orbit, habitable laboratory for science and research activities, including flight and test hardware and software, flight demonstrations for risk mitigation, ground operations capability and facility construction, shuttle hardware and integration for assembly and operation of the station, mission planning, and integration of Space Station systems.

Space Station elements will be provided by the U.S. and our international partners. The U.S. elements include two nodes, a laboratory module, truss segments, four photovoltaic arrays, a habitation module, three pressurized mating adapters, a cupola, unpressurized logistics carriers and a centrifuge accommodation module. Various systems are also being developed by the U.S. including thermal control, life support, navigation and propulsion, command and data handling, power systems, and internal audio/video. The U.S. elements also include the FGB energy tug, being provided by a Russian firm under the Boeing prime contract, and pressurized logistics modules, provided by Italy.

Canada, the European nations, Japan, and Russia are also developing hardware for the International Space Station program. Laboratory elements will be provided by the Japanese and European Space Agencies. Canada will provide the remote manipulator system, vital for assembly of the station. The Russian Space Agency is providing experiment, power, life support and service modules, Soyuz crew transfer vehicle, and universal docking modules.

The Johnson Space Center (JSC) has lead center management responsibility for the International Space Station program. In addition, specific JSC technical responsibilities include development of a set of facilities and systems to conduct the operations of the Space Station including on-orbit control of the Space Station.

The Center also provides institutional personnel as well as engineering and testbed support to the Space Station program. This includes test capabilities, the provision of Government Furnished Equipment (GFE), and engineering analysis support for the work of the prime contractor, its major subcontractors, and NASA system engineering and integration efforts.

SPACE SHUTTLE - JSC has lead center management responsibility for the Space Shuttle. In addition, JSC will provide development, integration, and operations support for the Mission Control Center (MCC), the Shuttle Mission Simulator (SMS), and other ground facilities needed for Space Shuttle Operations. JSC will provide Space Shuttle operational flight program management including system integration, crew equipment modification and processing, crew training, flight mission planning and operations, and procurement of Orbiter hardware.

PAYLOAD AND UTILIZATION OPERATIONS - JSC conducts concept studies and development on flight systems and options for human transportation. JSC provided support to the last flight of Spacelab in FY 1998. Other JSC activities include the engineering and technical base, payload operations and support equipment, and technology program support. Under this program, the X-38 experimental vehicle is being developed to demonstrate the technologies and processes required to produce crew return vehicle.

SPACE SCIENCE - The Center supports the Agency's planetary science program in the area of geosciences required to support future programs, provide curatorial support including distribution of samples for research and dissemination of information for lunar materials, U. S. Antarctic meteorites, and other materials from the solar system, and interact with outside scientists. This research focuses on the composition, structures, and evolutionary histories of the solid bodies of the universe.

LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS - JSC is the Lead Center for the following programs/functions; Biomedical Research and Countermeasures (BR&C); Advanced Human Support Technologies (AHST); and Space Medicine Research (SMR). It also has a supporting role in the Microgravity Research program in biotechnology. As Lead Center for BR&C, AHST, and SMR, JSC will integrate all supporting center activities relative to completing assigned HEDS goals and objectives. As part of the Space Medicine and Biomedical Research and Countermeasures activities, JSC will evaluate human physiological changes associated with the space flight environment and develop effective countermeasures to assure crew health and optimal performance during all phases of flight. The JSC will continue to expand the role and incorporate the National Space Biomedical Research Institute (NSBRI) into all relative aspects of the BR&C program. JSC will define and develop on-board health care systems and environmental monitoring systems; crew medical training; ground-based medical support of missions; develop a longitudinal crew health data base; and develop medical and psychological crew selection criteria. JSC will develop and integrate all science flight experiments for space flight missions; operate integrated payload systems; and train mission and payload specialists in the science aspect of their missions. In support of microgravity research, the JSC has established a center for support of biotechnology applications in Microgravity in order to study growth factors, medical chemo/immunotherapeutic, and human tissue transplantation.

MISSION/SPACE COMMUNICATION SERVICES - The Space Operations Management Office (SOMO), manages the telecommunication, data processing, mission operation, and mission planning services needed to ensure the goals of NASA's exploration, science, and research and development programs are met in an integrated and cost-effective manner. NASA's Space Communications/Operations program is composed of ground networks, mission control and data systems, and space network elements. Included within the space network is the management at GSFC of NASA's Tracking and Data Relay Satellite System (TDRSS).

CENTER MANAGEMENT AND OPERATIONS - Provides management, administrative, and financial oversight of NASA programmatic elements under JSC cognizance. In addition, the center provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

JOHNSON SPACE CENTER

	FY 1998	FY 1999	FY 2000
Space station	1,144	1,269	1,180
U.S./Russian cooperative program	16	12	0
Space shuttle	1,070	1,055	995
Payload and ELV Support	187	8	7
Space science	45	27	27
Life and microgravity sciences	126	110	110
Earth Sciences	0	0	0
Aero-space technology	0	0	0
Advanced space transportation program	6	6	6
Commercial technology programs	13	11	11
Academic programs	7	5	5
Mission communication services	35	33	33
Space communications services	2	2	2
Safety, reliability and quality assurance	2	2	2
Construction of facilities	26	17	14
Subtotal, direct full-time equivalents	2.679	2,557	2,392
Program management (Headquarters)	0	0	0
Center management and operations	468	435	427
Total, full-time equivalents	3.147	2,992	2,819

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

JOHN F. KENNEDY SPACE CENTER

ROLES AND MISSIONS

SPACE STATION - The Kennedy Space Center (KSC) is a supporting center for the Space Station Program. The KSC has developed a set of facilities, systems, and capabilities to conduct the operations of the Space Station. KSC develops launch site operations capabilities for conducting prelaunch and post-landing ground operations including integrated testing, interface verification, servicing, launch activities, and experiment-to-rack physical integration. The KSC provides launch site logistics support, resupply and customer utilization. The KSC serves as the primary agent for management and integration of ground processes for all U.S. launched International Space Station (ISS) elements from manufacture and assembly through verification and launch. The KSC develops and maintains ISS flight systems expertise to support the ISS- on orbit-mission and retain technical and operational experience within NASA & KSC for ground processing and verification of space flight hardware for follow-on programs.

SPACE SHUTTLE - The KSC is a supporting center for the Space Shuttle Program. The KSC provides Space Shuttle launch preparation, including orbiter processing and Ground Support Equipment (GSE) logistics; and operation and maintenance of GSE. The KSC develops a set of facilities, systems, and capabilities to conduct launch and recovery operations, including development of new launch and recovery operations concepts, techniques, and associated hardware.

PAYLOAD AND UTILIZATION OPERATIONS - The KSC is the Lead Center for Payload Carriers, and Payload Processing and Support Programs. The KSC provides support for all payload experiment integration, upper stages processing, ground support equipment (GSE) logistics and operations and maintenance of GSE. The KSC develops, activates, validates operates and maintains Payload Carrier facility systems, GSE, and processes to enable efficient launch site processing of Payload Carrier payloads.

EXPENDABLE LAUNCH VEHICLES - The KSC serves as the Lead Center for the acquisition and management of Expendable Launch Vehicle (ELV) Services. The KSC assures customer support through mission design and analysis, trade studies, and verification of launch vehicle performance requirements. The KSC provides government oversight of all launch vehicle and payload processing and checkout activities for all NASA contracted expendable launch vehicle and upper stage launch services both at the KSC and the Vandenburg Air Force Base. The KSC develops, activates, validates, operates and maintains ELV facility systems, GSE, and processes to enable efficient launch site processing of ELV.

CENTER MANAGEMENT AND OPERATIONS - The KSC provides administrative and financial services in support of Center management and provide for the operation and maintenance of the institutional facilities, systems, laboratories, test beds, associated technical infrastructure, and equipment. The KSC is delegated functional management responsibility for Agency liquid propellant consumables, liquid hydrogen and helium, and provides selected fluids for various Federal Government Agencies.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

KENNEDY SPACE CENTER

	FY 1998	FY 1999	FY 2000
Space station	322	352	346
U.S./Russian cooperative program	0	0	0
Space shuttle	767	730	699
Payload and ELV Support	231	217	211
Space science	0	0	0
Life and microgravity sciences	19	16	16
Earth Sciences	0	0	0
Aero-space technology	0	0	0
Advanced space transportation program	18	10	11
Commercial technology programs	12	15	13
Academic programs	0	0	0
Mission communication services	0	0	0
Space communications services	0	0	0
Safety, reliability and quality assurance	18	21	17
Construction of facilities	3	3	3
Subtotal, direct full-time equivalents	1,390	1,364	1,316
Program management (Headquarters)	0	0	0
Center management and operations	479	420	317
Total, full-time equivalents	1,869	1,784	1,633

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

GEORGE C. MARSHALL SPACE FLIGHT CENTER

ROLES AND MISSIONS

SPACE STATION – The Marshall Space Flight Center (MSFC) provides engineering support to the program including engineering analysis in support of the station system engineering and integration effort and the work of the prime and major subcontractors. In addition MSFC has the responsibility for the development of the Environmental Control and Life Support (ECLS) system as well as responsibility for the management and engineering oversight of the Italian Space Agency in the development of Nodes 2 and 3. Included also are the logistics carriers development and maintenance activities and the design integration of cargo elements for Station mission assembly and logistics supply flights. It is be responsible for developing payload utilization capabilities and planning and executing payload integration and operations activities. This includes the development and operation of the EXPRESS Rack and Pallet payload carriers, the payload operations integration center, and data systems. MSFC is also responsible for the management of all Microgravity Research projects to be implemented on the ISS.

SPACE SHUTTLE – As the Center of Excellence for establishing, upgrading, and maintaining world class excellence in space propulsion programs, MSFC provides for the design, development, and procurement for propulsion elements for the Space Shuttle Transportation (STS) system for contracts not assigned to the Space Flight Operations Contractor.

SPACE SCIENCE – MSFC has led the development and operations of the Advanced X-Ray Astrophysics Facility (AXAF) being launched in 1999. MSFC is also responsible for the development and operations of the Relativity Mission (Gravity Probe-B) planned for launch in late 2000, as well as management of selected payloads. As Center of Excellence for Optics, MSFC provides design and development support to the Goddard Space Flight Center and Jet Propulsion Laboratory.

LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS – As NASA's Lead Center for Microgravity Research, MSFC has responsibility for NASA's Microgravity initiatives, generating and communicating valuable knowledge of basic and applied physical, chemical and biological processes that are affected or hidden by the effects of gravity on Earth, and facilitating the use of space for the development of commercial products and services. MSFC performs research in the areas of materials science and biotechnology and will manage peer selected research and define and develop facilities and hardware apparatus necessary to achieve research objectives. MSFC also focuses on developing and transferring to the private sector the technology and applications of products developed for space.

AERO-SPACE TECHNOLOGY – The Center provides space transportation system and propulsion technologies to reduce cost and schedule risk in the development of next generation space transportation vehicles. It develops advanced propulsion and airframe system technologies to support ground and flight demonstration projects, while focusing on future break through technologies. The Center will conduct technology efforts, under contract including cooperative agreements, with the U.S. launch vehicle industry, to improve the competitiveness of current systems.

EARTH SCIENCE - MSFC is studying the interrelationship of global-scale climate processes and regional-scale hydrology, which is the science of water's distribution and variability over Earth, its integrating role in linking the planet's physical, biogeochemical, and geophysical fluid subsystems, and the associated human dimensions of Earth system variability. Utilizing global observations and information systems, improved and validated predictive models will be developed. MSFC will also lead in the establishment and operation of the Global Hydrology and Climate Center

MISSION/SPACE COMMUNICATION SERVICES - MSFC manage and maintains the NASA Integrated Services Network (NISN) - NISN services provide communications hardware, software, and transmission medium that inter-connects NASA Headquarters, installations, universities, and major contractor locations for the transfer of data, voice, and video.

CENTER MANAGEMENT AND OPERATIONS - MSFC provides administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems, and equipment. MSFC is the lead center for the development and implementation of the NASA Automation Consolidation Center (NACC), Agency Consolidated Payroll, Earned Value Performance Management, and Agency Logistics Business Systems Operations and Maintenance.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

MARSHALL SPACE FLIGHT CENTER

	FY 1998	FY 1999	FY 2000
Space station	493	561	596
U.S./Russian cooperative program	13	15	15
Space shuttle	394	325	301
Payload and ELV Support	12	11	6
Space science	302	269	179
Life and microgravity sciences	156	155	190
Earth Sciences	104	94	74
Aero-space technology	0	0	0
Advanced space transportation program	603	555	558
Commercial technology programs	66	45	45
Academic programs	10	10	9
Mission communication services	1	0	0
Space communications services	11	17	8
Safety, reliability and quality assurance	10	11	9
Construction of facilities	16	32	12
Subtotal, direct full-time equivalents	**2,191**	**2,100**	**2,002**
Program management (Headquarters)	0	0	
Center management and operations	631	590	523
Total, full-time equivalents	**2,822**	**2,690**	**2,525**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

JOHN C. STENNIS SPACE CENTER

ROLES AND MISSIONS

HUMAN SPACE FLIGHT - As the Lead Center for Propulsion Testing, SSC operates, maintains, and manages a propulsion test center and related capabilities for development, certification, and acceptance of rocket propulsion systems and components. The Center provides, maintains and manages the facilities and the related capabilities required for the continued development and acceptance testing of the Space Shuttle Main Engines. SSC also maintains and supports the Center's technical core laboratory and operations to enable SSC to conduct advanced propulsion test technology research and development for government and commercial propulsion programs.

EARTH SCIENCE - Through the Commercial Remote Sensing Program, SSC will undertake commercial partnership programs that apply remote sensing technologies in business applications and reduce new product development costs. As part of the Applied Research and Data Analysis program, SSC conducts fundamental and applied research which increase our understanding of environmental systems sciences, with emphasis on coastal research of both land and oceans.

AERO-SPACE TECHNOLOGY - Through the Technology Transfer and Small Business Innovative Research programs, SSC broadens and accelerates the development of spin-off technologies derived from national investments in aerospace research. SSC will also support the development of new and innovative propulsion technologies through the Advanced Space Transportation Program that supports the agency goal of reducing the cost of access to space.

CENTER MANAGEMENT AND OPERATIONS - The Center provides operates, maintains, and manages the institutional base and laboratories required to support and accomplish assigned programs of NASA and, on a reimbursable basis, other Federal and State agencies and organizations resident at the SSC.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

STENNIS SPACE CENTER

	FY 1998	FY 1999	FY 2000
Space station	0	0	0
U.S./Russian cooperative program	0	0	0
Space shuttle	34	30	21
Payload and ELV Support	0	0	0
Space science	0	0	0
Life and microgravity sciences	0	0	0
Earth Sciences	22	33	33
Aero-space technology	0	1	0
Advanced space transportation program	46	42	33
Commercial technology programs	3	3	3
Academic programs	4	5	5
Mission communication services	0	0	0
Space communications services	0	0	0
Safety, reliability and quality assurance	1	2	2
Construction of facilities	33	34	52
Subtotal, direct full-time equivalents	**143**	**150**	**149**
Program management (Headquarters)	0	0	0
Center management and operations	101	110	111
Total, full-time equivalents	**244**	**260**	**260**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

GODDARD SPACE FLIGHT CENTER

ROLES AND MISSIONS

SPACE SHUTTLE/PAYLOAD AND UTILIZATION OPERATIONS - GSFC manages flights of the Hitchhiker, a reusable carrier system which provides increased flight opportunities with reduced lead-time while maximizing Space Shuttle load factors and minimizing spaceflight costs. GSFC also manages and coordinates the Agency's Get Away Special (GAS) program.

SPACE SCIENCE - GSFC manages physics and astronomy activities in the following discipline areas: gamma ray astronomy, X-ray astronomy, ultraviolet and optical astronomy, infrared and radio astronomy, particle astrophysics, solar physics, interplanetary physics, planetary magnetospheres, and astrochemistry. GSFC also is responsible for conducting the mission operations for a variety of operating spacecraft. Other activities include managing NASA's sounding rocket and scientific balloon program.

GSFC also conducts planetary exploration research into the physics of interplanetary and planetary space environments and participates in planetary mission instrument development, operations, and data analysis. GSFC develops technologies targeted at improved spaceborne instruments, and on-board spacecraft systems and subsystems.

EARTH SCIENCE - GSFC is the Lead Center for Earth Science, including the Earth Observing System (EOS). The primary objective of the EOS is to collect data on global change and to observe regional-to-global processes. The EOS will document global change over a fifteen-year period to provide long-term, consistent data sets for use in modeling and understanding global processes. This process and modeling research effort will provide the basis for establishing predictive global change models for policy makers and scientists.

Manages Earth Probes and New Millennium flight projects; manages, on a reimbursable basis, the acquisition of meteorological observing spacecraft for the National Oceanic and Atmospheric Administration (NOAA). Goddard conducts science correlation measurements from balloons, sounding rockets, aircraft, and ground installations support to interagency NASA/NOAA/DOD.

AERO-SPACE TECHNOLOGY - The Wallops Flight Facility conducts flight studies of new approach and landing procedures using the latest in guidance equipment and techniques, pilot information displays, human factors data, and terminal area navigation. As an integral partner in the Agency's High Performance Computing and Communications (HPCC) program, GSFC leads an effort to enhance the infusion of HPCC technologies into the Earth and space science community through the provision of advanced computer architectures and communication technologies. GSFC promotes private sector investment in space-based technologies through the transfer of technologies that derive from NASA's programs and activities.

MISSION/SPACE COMMUNICATION SERVICES - Research and technology involves the investigation and development of advanced systems and techniques for spacecraft communications and tracking, command and control, and data acquisition and processing. The primary objectives are to apply technology and develop advanced capabilities to meet the tracking and data processing requirements of new missions and to improve the cost effectiveness and reliability of flight mission support.

Although the Johnson Space Center is designated as the Space Operations Lead Center, GSFC manages a number of critical program elements, including operation of the Tracking and Data Relay Satellite System (TDRSS); the development of the replenishment TDRSS spacecraft; mission control, data processing, and orbit/attitude computation support; operating the Space Tracking and Data Network (STDN), the NASA Communications (NASCOM) Network, and the Aeronautics, Balloons and Sounding Rocket Program.

The NASCOM Network links the stations of the Deep Space Network (DSN), STDN, TDRSS, and other tracking and data acquisition elements with control centers and data processing and computation centers.

CENTER MANAGEMENT AND OPERATIONS - Provides administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

GODDARD SPACE FLIGHT CENTER

	FY 1998	FY 1999	FY 2000
Space station	0	0	0
U.S./Russian cooperative program	0	0	0
Space shuttle	4	4	4
Payload and ELV Support	50	56	56
Space science	1,011	1,045	1,045
Life and microgravity sciences	0	0	0
Earth Sciences	1,070	981	1,024
Aero-space technology	12	4	0
Advanced space transportation program	0	0	0
Commercial technology programs	22	23	23
Academic programs	0	0	0
Mission communication services	186	180	120
Space communications services	70	78	72
Safety, reliability and quality assurance	21	8	7
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	**2,446**	**2,379**	**2,351**
Program management (Headquarters)	0	0	0
Center management and operations	892	972	953
Total, full-time equivalents	**3,338**	**3,351**	**3,304**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

AMES RESEARCH CENTER

ROLES AND MISSIONS

AERO-SPACE TECHNOLOGY - *ARC* conducts aeronautics research in ground-based and airborne automation technologies, human factors and operational methodologies for efficient, safe and effective airspace operations. *ARC* develops an integrated set of experimental and computational technologies built around an embedded information systems backbone, to provide rapid, accurate vehicle synthesis and testing capabilities. *ARC* conducts research spanning computation through flight, for Rotorcraft and Powered Lift configurations and for high performance aircraft to improve efficiency, affordability. and performance. *ARC* continues an interdisciplinary research program which provides the technology base for the development of subsonic and high speed transport aircraft. The center emphasizes joint research and technology projects with other NASA installations, government agencies, industry and academia.

ARC will strengthen basic research and technology development for aerospace systems that transport humans and instrumentation to and from space and within the atmospheres of other bodies within the solar system. The center conducts research thermal protection systems and arcjet testing is performed to meet national needs for access to space and planetary exploration.

SPACE SCIENCE - Ames has the agency lead role in Astrobiology (the study of life in the universe) which in Space Science focuses on the origin of life and its possible development on other worlds. Research includes advanced laboratory and computation facilities for astrochemistry; planetary atmosphere modeling, including relationships to the atmosphere of the Earth: the formation of stars and planetary systems: and an infrared technology program to investigate the nature and evolution of astronomical systems. Development of the Stratospheric Observatory for Infrared Astronomy (SOFIA) will continue. Research and development (R&D) in advanced information technologies are directed toward significantly increasing the efficiency of SOFIA as it becomes operational. Ames also is the lead center for information technology efforts in the cross-enterprise spacecraft technology program funded in space science.

LIFE AND MICROGRAVITY SCIENCES - Ames has the agency lead role in Astrobiology and Gravitational Biology and Ecology programs. These synergistic programs examine the adoption of life forms to reduced gravity and the evolution and distribution of life in the universe. Research continues into the effects of gravity on living systems using spaceflight experiments, ground simulation, and hypergravity facilities to understand the how gravity affects the development, structure and functions of living systems. Also studied are options for preventing problems in crew health and psychophysiology during and after extended spaceflight. Ames has a primary focus on advanced physical/chemical technologies for life support, including research into all aspects of regenerative life support. Research is conducted in the areas of ecosystems and health monitoring.

EARTH SCIENCE - Ames has the agency lead role in Astrobiology which in Earth Science focuses on the relationship between life on Earth and our changing environment. Instruments and computer models for the measurement and analysis of atmospheric constituents and properties from aircraft platform are being developed. Applied research and developments to enhance the use of remote and in-situ sensing technology for Earth resources applications continues.

SAFETY, RELIABILITY AND QUALITY ASSURANCE – ARC will provide institutional safety and health programs and develop and integrate Safety, Reliability and Quality Assurance guidelines into program and project development.

CENTER MANAGEMENT AND OPERATIONS – ARC will provide administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

AMES RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	37	55	76
U.S./Russian cooperative program	0	0	0
Space shuttle	0	0	0
Payload and ELV Support	0	0	0
Space science	175	172	173
Life and microgravity sciences	89	72	54
Earth Sciences	45	44	44
Aero-space technology	657	662	637
Advanced space transportation program	69	66	86
Commercial technology programs	1	1	1
Academic programs	2	2	2
Mission communication services	0	0	0
Space communications services	0	0	0
Safety, reliability and quality assurance	10	10	9
Construction of facilities	25	25	25
Subtotal, direct full-time equivalents	**1,110**	**1,109**	**1,107**
Program management (Headquarters)	0	0	0
Center management and operations	368	348	350
Total, full-time equivalents	**1,478**	**1,457**	**1,457**

DRYDEN FLIGHT RESEARCH CENTER

CENTER ROLES AND MISSIONS

AERO-SPACE TECHNOLOGY - Develop, manage, and maintain facilities and testbed aircraft to support safe, timely, and cost effective NASA flight research and to support industry, university, and other government agency flight programs.

Conceive, formulate, and conduct piloted and unpiloted research programs in disciplinary technology. integrated aeronautical systems, and advanced concepts to meet durrent and future missions throughout subsonic, supersonic, and hypersonic flight regimes.

Conduct flight research programs in cooperation with other NASA Installations, other government agencies, the aerospace industry, and universities. Transition results, techniques, methods, and tools to industry and government users in a timely manner.

DFRC will also provide flight test support for atmospheric tests of experimental or developmental launch systems, including reusable systems.

SPACE SHUTTLE / PAYLOAD AND UTILIZATION OPERATIONS - The DFRC provides operational and technical support for the conduct of Space Shuttle missions, including on-orbit tracking and communications, landing support of crew and science requirements.

CENTER MANAGEMENT AND OPERATIONS – DFRC will provide administrative services in support of Center management and provides for the operation and maintenance of the Institutional facilities. systems and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

DRYDEN FLIGHT RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	0	20	30
U.S./Russian cooperative program	0	0	0
Space shuttle	26	9	9
Payload and ELV Support	0	0	0
Space science	0	0	0
Life and microgravity sciences	0	0	0
Earth Sciences	30	39	39
Aero-space technology	283	326	336
Advanced space transportation program	77	93	90
Commercial technology programs	4	4	4
Academic programs	0	0	0
Mission communication services	19	19	19
Space communications services	0	0	0
Safety, reliability and quality assurance	12	1	1
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	**451**	**511**	**528**
Program management (Headquarters)	0	0	0
Center management and operations	107	125	106
Total, full-time equivalents	**558**	**636**	**634**

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATE

LANGLEY RESEARCH CENTER

ROLES AND MISSIONS

AERO-SPACE TECHNOLOGY - Conduct advanced research in fundamental aerodynamics; high-speed, highly maneuverable aircraft technology; hypersonic propulsion; guidance and controls; acoustics; and structures and materials. Develop a technology base for improving transport, fighter, general aviation, and commuter aircraft. Conduct an aeronautical research and technology program to study current and future technology requirements and to demonstrate technology applications. Conduct theoretical and experimental research in fluid and flight mechanics to determine aerodynamic flows and complex aircraft motions.

Develop innovative new airframe systems to improve safety and significantly reduce cost per seat mile of commercial transport aircraft and reduce emissions to improve environmental compatibility. Pioneer the development of new materials, structural concepts, and fabricate technologies to revolutionize the cost, performance, and safety of future aircraft structures for radically new aircraft design.

Study critical environmental compatibility issues in order to make decisions on future high speed civil transport technology and development programs. Develop technology options for realization of practical hypersonic and transatmospheric flight.

Conduct control and guidance research programs to advance technology in aircraft guidance and navigation, aircraft control systems, cockpit systems integration and interfacing techniques, and performance validation and verification methods. Conduct research in aircraft noise prediction and abatement.

Conduct aeronautics and space research and technology development for advanced aerospace transportation systems, including hypersonic aircraft, missiles, and space access vehicles using airbreathing and rocket propulsion. Specific technology discipline areas of expertise are aerodynamics, aerothermodynamics, structures, materials, hypersonic propulsion, guidance and controls, and systems analysis. Conduct long-range studies directed at defining the technology requirements for advanced transportation systems and missions.

EARTH SCIENCE - Perform an agency-designated Atmospheric Science mission role in support of the Earth Science Enterprise in the NASA Strategic Plan. Conduct a world-class peer reviewed and selected atmospheric science program in support of national goals in preserving the environment and in fundamental science. Specific discipline areas of expertise are Earth radiation research, particularly the role of clouds in the Earth's energy budget; middle and upper atmospheric research; and troposhperic research. Perform innovative scientific research to advance the knowledge of atmospheric radiative, chemical, and dynamic processes for understanding global change; develop innovative passive and active sensor systems concepts for atmospheric science measurements; explore advanced laser and LIDAR technologies for Earth science missions; develop advanced ultra-lightweight and adaptive materials, structural systems technologies and analytical tools for significantly reducing the end-to-end cost and increasing the performance of earth observation space instruments and systems. Serve as a Primary Data Analysis and Archival Center (DAAC) for Earth Radiation and Atmospheric Chemistry for the Earth Observing System.

SPACE SCIENCES –LaRC will support the solicitation and selection process of the Office of Space Science's (OSS) Discovery, Explorer and Solar Terrestrial Probes Programs; conduct reviews of candidate and selected missions and independent assessments of on-going space science missions to help ensure that OSS criteria for high quality science return within cost and schedule constrains are met; develop advanced ultra-lightweight and adaptive materials, structural systems technologies and analytical tools for significantly reducing the end-to-end cost and increasing the performance of space science instruments and systems. Langley is developing the SABER instrument which will be on the TIMED mission to explore the mesosphere and lower thermosphere globally and achieve a major improvement in the understanding of the fundamental processes governing energetics, chemistry, dynamics and transport. Langley is also analyzing SAMPEX data to assess the relative importance of solar terrestrial coupling due to varying electron precipitation compared to that due to 11-year solar flux variations.

LIFE AND MICROGRAVITY SCIENCES – LaRC conducts space radiation exposure studies in support of current and future human space efforts for a more accurate assessment of astronaut radiation exposures and body shielding factors.

SYSTEMS ANALYSIS/INDEPENDENT PROGRAM EVALUATION AND ASSESSMENT – Langley serves as the Agency lead center for systems analysis and the conduct of independent evaluation and assessment of Agency programs. Maintain, as a Center core competency, appropriate expertise and analysis tools to support the Agency's Strategic Enterprises in the definition and development of advanced systems concepts to achieve NASA's goals. The Center utilizes core systems analysis capabilities (supplemented with expertise from other Centers as appropriate) to support the Office of the Administrator by conducting independent assessments of advanced concepts and proposed new systems to validate conceptual level designs prior to Agency commitment to major developmental funding. LaRC supports the Administrator's Program Management Council (PMC) in the organization, administration, and technical support of PMC review process.

SAFETY, RELIABILITY, AND QUALITY ASSURANCE – The Center will provide a Safety, Reliability, and Quality Assurance program that conducts independent assessment activities which reduce program risk.

CENTER MANAGEMENT AND OPERATIONS – LaRC will provide administrative and financial services in support of Center management and provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

LANGLEY RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	8	11	17
U.S./Russian cooperative program	0	0	0
Space shuttle	2	0	0
Payload and ELV Support	40	28	22
Space science	59	74	85
Life and microgravity sciences	7	7	0
Earth Sciences	239	265	271
Aero-space technology	1,313	1,250	1,236
Advanced space transportation program	148	148	167
Commercial technology programs	33	33	33
Academic programs	0	0	0
Mission communication services	0	0	0
Space communications services	0	11	11
Safety, reliability and quality assurance	2	4	4
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	1,851	1,831	1,846
Program management (Headquarters)	0	0	0
Center management and operations	569	558	528
Total, full-time equivalents	2,420	2,389	2,374

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

GLENN RESEARCH CENTER

ROLES AND MISSIONS

LIFE AND MICROGRAVITY SCIENCES - The Glen Research Center (GRC) provides leadership and management of the fluid physics, combustion science, acceleration measurement and telescience disciplines of NASA's Microgravity Science Program. GRC conducts and sponsors ground-based scientific studies that may lead to experiments in space. The center has a substantial effort in the design, buildup, testing, and integration of hardware for experiment packages to be launched aboard the Space Shuttle and the utilization of the Space Station for scientific missions.

SPACE STATION – GRC support to the space station program includes technical and management support in the areas of power and on-board propulsion components and system, engineering and analysis, technical expertise, and testing for components and systems. This includes use of facilities and testbeds and construction of flight hardware as required.

MISSION COMMUNICATIONS SERVICES - GRC manages and operates the Advanced Communications Technology Satellite (ACTS) to prove highrisk communication technologies, to transfer the knowledge gained to US satellite industry developers and users, and to reaffirm the US satellite communications preeminence in this rapidly growing world-wide market. The Center also ensures timely and high quality availability of radio frequency spectrum to enable the realization of NASA goals; actively stimulating the effective use of (ACTS).

AERO-SPACE TECHNOLOGY - As the NASA Lead Center for Aeropropulsion, GLC conducts world-class research critical to the Agency Aeronautics Enterprise goals of developing and transferring enabling technologies to U.S. industry and other government agencies. The Center's Aeropropulsion program is essential to achieving National goals to promote economic growth and national security through safe, superior, and environmentally compatible U.S. civil and military aircraft propulsion systems. The Aeropropulsion Program spans subsonic, supersonic, hypersonic, general aviation, and high performance aircraft propulsion systems through innovative application of research in materials, structures, internal fluid mechanics, instrumentation and controls, interdisciplinary technologies, and aircraft icing.

As the NASA Center of Excellence in Turbomachinery, GRC's expertise is critical to advancing the Agency's goals in the aeronautics and space programs. This designation enables GRC to be a cost-effective resource across multiple Agency programs in the vital and strategic discipline area of turbomachinery. Areas of expertise include air breathing propulsion and power systems, primary and auxiliary propulsion and power systems, on-board propulsion systems, and rotating machinery for the pumping of fuels.

CENTER MANAGEMENT AND OPERATIONS - Provides administrative and financial services in support of Center Management and provides for the operation and maintenance of the institutional facilities, systems, and equipment.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

LEWIS RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	153	274	318
U.S./Russian cooperative program	0	0	0
Space shuttle	22	0	0
Payload and ELV Support	9	0	0
Space science	188	187	187
Life and microgravity sciences	171	135	108
Earth Sciences	17	7	0
Aero-space technology	926	846	772
Advanced space transportation program	106	112	138
Commercial technology programs	17	14	14
Academic programs	5	4	3
Mission communication services	50	51	51
Space communications services	5	0	0
Safety, reliability and quality assurance	10	8	8
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	1,679	1,638	1,599
Program management (Headquarters)	0	0	0
Center management and operations	395	365	384
Total, full-time equivalents	2,074	2,003	1,983

RESEARCH AND PROGRAM MANAGEMENT

FISCAL YEAR 2000 ESTIMATES

NASA HEADQUARTERS

ROLES AND MISSIONS

NASA Corporate Headquarters

MISSION - The mission of Headquarters is to plan and provide executive direction for the implementation of U. S. space exploration, space science, aeronautics, and technology programs. This includes corporate policy development, program formulation, resource allocations, program performance assessment, long-term institutional investments, and external advocacy for all of NASA.

MAJOR CORPORATE ROLES - At NASA Headquarters, the broad framework for program formulation will be conducted through four Strategic Enterprises: Human Exploration and Development of Space, Earth Science, Aeronautics and Space Transportation Technology, and Space Science. Consistent with the NASA strategic plan, the Strategic Enterprises develop program goals and objectives to meet the needs of external customers within the policy priorities of the Administration and Congress.

Corporate level enabling processes and staff functions will provide cross-cutting interfaces required to support the Strategic Enterprises in legislative affairs, public affairs, budget and financial management, equal opportunity programs, human resources, education, legal affairs, procurement, international affairs, management systems and facilities, information systems and technology, small business, safety and mission quality, advisory committees, and policy and plans.

The Office of Headquarters Operations provides and manages the infrastructure necessary to support the Headquarters installation.

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

NASA HEADQUARTERS

	FY 1998	FY 1999	FY 2000
Space station	15	18	12
U.S./Russian cooperative program	3	0	0
Space shuttle	22	19	14
Payload and ELV Support	4	4	4
Space science	91	91	91
Life and microgravity sciences	33	34	34
Earth Sciences	33	33	33
Aero-space technology	44	37	37
Advanced space transportation program	5	5	5
Commercial technology programs	10	10	10
Academic programs	9	9	9
Mission communication services	5	0	0
Space communications services	3	0	0
Safety, reliability and quality assurance	42	43	43
Construction of facilities	17	17	17
Subtotal, direct full-time equivalents	**336**	**320**	**309**
Program management (Headquarters)	47	46	44
Center management and operations	591	617	628
Total, full-time equivalents	**974**	**983**	**981**

DETAIL OF PERMANENT POSITIONS

	FY 1998	FY 1999	FY 2000
Executive level II	1	1	1
Executive level IV	2	2	2
Subtotal	**3**	**3**	**3**
ES-6	50	50	50
ES-5	109	109	109
ES-4	167	167	167
ES-3	70	70	70
ES-2	62	62	62
ES-1	47	47	47
Subtotal	**505**	**505**	**505**
CA	1	1	1
SL/ST	61	60	59
GS-15	2236	2184	2131
GS-14	3496	3414	3332
GS-13	6086	5943	5801
GS-12	1862	1818	1775
GS-11	1197	1169	1141
GS-10	258	252	246
GS-9	443	433	422
GS-8	241	235	230
GS-7	605	591	577
GS-6	533	521	508
GS-5	93	91	89
GS-4	16	16	15
GS-3	4	4	4
GS-2	0	1	1
Subtotal	**17,132**	**16,732**	**16,331**
Sp ungraded positions established by NASA Admin.	25	25	25
Ungraded positions	355	355	355
Total permanent positions	**18,020**	**17,620**	**17,219**
Unfilled positions, EOY	0	0	0
Total, permanent employment, EOY	**18,020**	**17,620**	**17,219**

PERSONNEL SUMMARY

	FY 1998	FY 1999	FY 2000
Average GS/GM grade	12.5	12.5	12.5
Average ES salary	$118,776	$121,450	$124,185
Average GS/GM salary	$64,477	$66,798	$69,737
Average salary of special ungraded positions established by NASA Administrator	$92,047	$95,361	$99,557
Average salary of ungraded positions	$44,619	$46,225	$48,259

CENTER LOCATIONS AND CAPITAL INVESTMENT

JOHNSON SPACE CENTER - The Lyndon B. Johnson Space Center is located 20 miles southeast of Houston, Texas. NASA owns 1,618 acres of land at the Houston site and uses another 60,552 at the White Sands Test Facility, Las Cruces, New Mexico. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $2,720,153,000 as of September 30, 1998.

KENNEDY SPACE CENTER - The Kennedy Space Center is located 50 miles east of Orlando, Florida. NASA owns 82,943 acres and uses launch facilities at Cape Canaveral Air Station and Vandenberg Air Force Base. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $1,592,393,000 as of September 30, 1998.

MARSHALL SPACE FLIGHT CENTER - The Marshall Space Flight Center is located within the U.S. Army's Redstone Arsenal at Huntsville, Alabama. MSFC also manages operation at the Michoud Assembly 15 miles east of New Orleans, Louisiana and the Slidell Computer Complex in Slidell, Louisiana. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $3,035,495,000 as of September 30, 1998.

STENNIS SPACE CENTER - The Stennis Space Center is located approximately 50 miles northeast of New Orleans, Louisiana. NASA owns 20,663 acres and has easements covering an additional 118,284 acres. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $360,186,000 as of September 30, 1998.

GODDARD SPACE FLIGHT CENTER - The Goddard Space Flight Center is located 15 miles northeast of Washington, D.C. at Greenbelt, Maryland. NASA owns 1,121 acres at this location and an additional 6,176 acres at the Wallops Flight Facility in Wallops Island, Virginia. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $2,563,817,000 as of September 30, 1998.

AMES RESEARCH CENTER - The Ames Research Center is located south of San Francisco on Moffett Field, California. NASA owns 447.5 acres at the Moffett Field location. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $915,036,000 as of September 30, 1998.

DRYDEN FLIGHT RESEARCH CENTER - The Dryden Flight Research Center is 65 air miles northeast of Los Angeles. Dryden is located at the north end of Edwards Air Force Base on 838 acres of land under a permit from the Air Force. The total replacement cost at Dryden, including fixed assets in progress and contractor-held facilities at various locations, as of September 30, 1998 was $388,775,000.

LANGLEY RESEARCH CENTER - The Langley Research Center is adjacent to Langley Air Force Base which is located between Williamsburg and Norfolk at Hampton, Virginia. NASA owns 788 acres and has access to 3,276 acres. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $1,053,165,000 as of September 30, 1998.

GLENN RESEARCH CENTER - The Glenn Research Center occupies two sites; the main site is in Cleveland, Ohio, adjacent to Cleveland-Hopkins Airport; the second site is the Plum Brook Station located south of Sandusky, Ohio, and 50 miles west of Cleveland. NASA owns 6,805 acres and leases an additional 14 acres at the Cleveland location. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $617,065,000 as September 30, 1998.

NASA HEADQUARTERS - NASA Headquarters is located at Two Independence Square, 300 E St. SW, Washington, D.C. and occupies other buildings in the District of Columbia, Maryland, and Virginia.

MISSION SUPPORT

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF MANAGEMENT SYSTEMS AND FACILITIES — **CONSTRUCTION OF FACILITIES**

SUMMARY OF RESOURCES REQUIREMENTS

	1998 OPLAN 9/29/98	1999 OPLAN 12/22/98	2000 PRES BUDGET	Page Number
	(Thousands of Dollars)			
International Space Station Appropriation	--	1,200	--	
Launch Vehicles and Payload Operations Appropriation	8,200	7,600	11,000	MS 4-8
Science, Aeronautics and Technology Appropriation	5,900	16,300	14,200	MS 4-15
*Mission Support Appropriation	122,400	168,500	181,000	MS 4-25
Total	136,500	193,600	206,200	

*See page 4-25 for center distribution.

PROGRAM GOALS

The goal of the Construction of Facilities program is to ensure that the facilities critical to achieving NASA's space and aeronautics program are functioning effectively, efficiently, and safely, and that NASA installations conform with requirements and initiatives for the protection of the environment and human health.

STRATEGY FOR ACHIEVING GOALS

NASA facilities are critical to the development and operation of the space transportation system. They are necessary to sustain payload and launch operations, as well as critical National aeronautical and aerospace testing capabilities, that also support military and private industry users.

The Construction of Facilities (CoF) budget line item in the Mission Support appropriation provides for Discrete projects required for components of the basic infrastructure and institutional facilities. Almost all of these projects are capital repair. The Mission Support appropriation also includes Minor Revitalization projects (repair, rehabilitation, modernization, and modification of existing facilities), Minor Construction projects, Environmental Compliance and Restoration activities, the design of facilities projects, and advanced planning related to future facilities needs. Funding for construction projects required to conduct specific Human Space Flight or Science, Aeronautics, and Technology programs or projects is included in the appropriate budget line item.

The Launch Vehicles and Payload Operations FY 2000 budget request provides Discrete projects to restore the wall and ceiling integrity of the Payload Changeout Room and the surfaces and slopes of Pad B at Kennedy Space Center and rehabilitate the 480 volt electrical distribution system in the External Tank Manufacturing Building at the Michoud Assembly Facility. It also includes minor projects less than $1,500,000 required to support specific programs. The Science, Aeronautics, and Technology budget request provides Discrete projects to restore the Meteorological Development Laboratory at Goddard Space Flight Center, replace the fan blades in the National Full-scale Aerodynamic Complex at Ames Research Center, replace the main drive in the 14x22-foot Subsonic Tunnel at Langley Research Center, and complete construction of an Optical Interferometry Development Laboratory at Jet Propulsion Laboratory.

Mission Support funding is requested in FY 2000 for Discrete projects to repair and modernize building and utility systems that have reached or exceeded their normal design life and cannot be economically maintained. These systems include mechanical, structural, cooling, steam, and electrical distribution at Ames Research Center, Dryden Flight Research Center, Goddard Space Flight Center, Johnson Space Center, Kennedy Space Center, Glenn Research Center and Marshall Space Flight Center. Also included are projects to rehabilitate the hydrostatic bearing runner on the 70-meter Antenna at Goldstone, Ca. and to upgrade the servo drives on the 70-meter antennas of the subnet. Should residual resources become available from these projects they will be used for urgently needed safety related facility requirements. Congress will be notified before work is initiated for any such project that exceeds $1,500,000.

The FY 2000 construction projects help preserve and enhance the capabilities and usefulness of existing facilities and ensure the safe, economical, and efficient use of the NASA physical plant. The Minor Revitalization program included in this request continues the necessary rehabilitation, modification, and repair of facilities. The Minor Construction program will primarily replace substandard facilities in cases where it is more economical to demolish and rebuild than it is to restore. In selected cases, additional square footage may be built when there are compelling reasons to support new or specialized technical and/or institutional requirements of a nature that cannot be provided by using existing facilities.

Funds requested for Facility Planning and Design cover advance planning and design requirements for potential future projects, preparation of facility project design drawings and bid specifications, master planning, facilities studies, and engineering reports and studies. Also included are critical functional leadership activities directed at increasing the rate of return of constrained Agency resources while keeping the facility infrastructure safe, reliable, and available.

Deferred Major Maintenance funding provides for projects that partially mitigate the Agency's growing backlog of maintenance and repair. Projects will be identified and prioritized based on the findings of the Agency's Core Capabilities Assessment currently underway.

The Environmental Compliance and Restoration (ECR) Program is critical to ensuring that statutory and regulatory environmental requirements and standards are met. NASA's environmental strategy demonstrates our commitment to protect the environment and provides for the protection and safety of human health. This commitment is achieved by focusing and directing our leadership and efforts into the four principal areas of compliance, remediation, restoration, and prevention. These areas provide the framework for meeting our current environmental needs and preparing NASA for future challenges. Concurrently, we are aggressively pursuing the use of the Energy Savings Performance Contracting (ESPC) mechanism to achieve the federal energy management goals for financing cost-effective energy conservation modifications at existing facilities.

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1998	FY 1999	FY 2000	Page Number
		(Thousands of Dollars)		
INTERNATIONAL SPACE STATION	--	1,200	--	
Minor Revitalization of Facilities at Various Locations, Not in excess of $1,500,000 per project	---	1,200	--	
LAUNCH VEHICLES AND PAYLAOD OPERATIONS	8,200	7,600	11,000	
Restore Pad Surfaces and Slopes, Pad B (KSC)	---	---	1,800	MS 4-9
Restore Wall and Ceiling Integrity, Payload Changeout Room, Pad B (KSC)	---	---	2,300	MS 4-11
Rehabilitate 480V Electrical Distribution System, External Tank Manufacturing Bldg. (MAF)	2,800	2,000	1,800	MS 4-13
Refurbish Pad A Fixed Support Structure Elevator System (KSC)	---	2,300	---	
Refurbish Pad A Flame Deflector and Trench (KSC)	---	1,500	---	
Repairs to Cleaning Cell E, Vertical Assembly Building (MAF)	---	1,800	---	
Repair of Payload Changeout Room Wall & Ceiling, Pad A (KSC)	2,200	---	---	
Restoration of Pad Surface & Slope, Pad A (KSC)	1,800	---	---	
Construct Landing Support Complex (SSC)	1,400	---	---	
Minor Revitalization of Facilities at Various Locations, Not in excess of $1,500,000 per project	---	--	2,400	
Facility Planning and Design	---	---	2,700	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1998	FY 1999	FY 2000	Page Number
		(Thousands of Dollars)		
SCIENCE, AERONAUTICS, AND TECHNOLOGY	5,900	16,300	14,200	
SPACE SCIENCE				
Construct Optical Interferometry Development Laboratory (JPL)	---	2,500	2,500	MS 4-16
Restore Meteorological Development Laboratory (GSFC)	---	2,500	---	
Modification of Stratospheric Observatory for Infrared Astronomy (SOFIA) Ground Support Facility (ARC)	---	7,300	---	
LIFE AND MICROGRAVITY SCIENCE AND APPLICATIONS				
Modifications for the Installation of the Bio-Plex (JSC)	2,200	---	---	
EARTH SCIENCE				
Restore Meteorological Development Laboratory (GSFC)	---	1,500	1,000	MS 4-19
AERO-SPACE TECHNOLOGY				
Replace Fan Blades, National Full-Scale Aerodynamic Complex (ARC)	---	2,000	3,400	MS 4-21
Replace Main Drive for 14x22-Foot Subsonic Tunnel (LaRC)	---	500	7,300	MS 4-23
Rehabilitation and Modification of Test Stands (SSC)	3,700	---	---	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1998	FY 1999	FY 2000	Page Number
		(Thousands of Dollars)		
MISSION SUPPORT				
Restore Electrical Distribution System (ARC)	---	2,200	2,700	MS 4-27
Rehabilitate Main Hangar Building 4802 (DFRC)	---	---	2,900	MS 4-29
Rehabilitate High Voltage System (GRC)	9,000	8,300	7,600	MS 4-31
Repair Site Steam Distribution System (GSFC)	---	2,000	2,900	MS 4-33
Restore Chilled Water Distribution System (GSFC)	2,171	---	3,900	MS 4-35
Rehabilitate Hydrostatic Bearing Runner, 70 meter Antenna, Goldstone (JPL)	---	---	1,700	MS 4-37
Upgrade 70 meter Antenna Servo Drive, 70 meter Antenna Subnet (JPL)	---	---	3,400	MS 4-39
Rehabilitate Utility Tunnel Structure and Systems (JSC)	---	---	5,600	MS 4-41
Connect KSC to CCAS Wastewater Treatment Plant (KSC)	---	---	2,500	MS 4-43
Repair and Modernize HVAC System, Central Instrument Facility (KSC)	---	---	3,000	MS 4-45
Replace High Voltage Load Break Switches (KSC)	---	---	2,700	MS 4-47
Repair and Modernize HVAC and Electrical Systems, Bldg. 4201 (MSFC)	---	---	2,300	MS 4-49
Repair Roofs, Vehicle Component Supply Buildings (MAF)	---	---	2,000	MS 4-51
Rehabilitation and Modification of Test Stands (SSC)	3,700	---	---	
Modernization of Process Cooling System, Numerical Aerodynamic Simulation Facility (ARC)	---	2,700	---	
Construct Data Interface Facility (DFRC)	---	2,000	---	
Restoration of Space/Terrestrial Application Facility (GSFC)	---	5,000	---	
Construction of In-Situ Instruments Laboratory (JPL)	---	5,000	---	
Replacement of Central Plant Chilled Water Equipment (JSC)	---	5,200	---	
Upgrade of Utility Annex Chilled Water Plant (KSC)	4,000	1,900	---	
Rehabilitation of Instrument Research Laboratory (LARC)	---	3,100	---	
Modification of Chilled Water System (MSFC)	6,700	7,200	---	
Rehabilitation and Modification of Hangar/Shop (DFRC)	2,700	---	---	

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMARY OF BUDGET PLAN BY APPROPRIATION AND PROJECT

INSTALLATION AND PROJECT	FY 1998	FY 1999	FY 2000	Page Number
		(Thousands of Dollars)		
MISSION SUPPORT (continued)				
Construction of Emergency Services Facility (JPL)	4,600	---	---	
Construction of Addition to Administration Building (SSC)	5,000	1,500	---	
Total Mission Support Discrete Projects	34,171	46,100	43,200	
Minor Revitalization of Facilities at Various Locations, Not in excess of $1,500,000 per project	56,729	68,400	65,500	MS 4-53
Minor Construction of New Facilities and Additions to Existing Facilities at Various Locations, Not in excess of $1,500,000 per project	1,100	---	5,000	MS 4-59
Facility Planning and Design	19,000	14,000	19,200	MS 4-62
Deferred Major Maintenance	---	---	8,000	MS 4-66
Environmental Compliance and Restoration	11,400	40,000	40,100	MS 4-69
Total - Mission Support	122,400	168,500	181,000	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

SUMMARY

LAUNCH VEHICLES AND PAYLOAD OPERATIONS

		Amount (Dollars)	Page No
Space Shuttle:			
Restore Pad Surfaces and Slopes, Pad B (KSC)		1,800,000	MS 4-9
Restore Wall and Ceiling Integrity, Payload Changeout Room, Pad B (KSC)		2,300,000	MS 4-11
Rehabilitate 480V Electrical Distribution System, External Tank Manufacturing Building (MAF)		1,800,000	MS 4-13
Minor Facility Projects at Various Locations, not in excess of $1,500,000 per project		2,400,000	
Repair and Modernize Space Shuttle Main Engine Test Stand A-2	(1,400,000)		
Construct Convoy Shelter and Staging Facility	(1,000,000)		
Facility Planning and Design		2,700,000	
Total Launch Vehicles and Payload Operations		11,000,000	

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Restore Pad Surfaces and Slopes, Pad B

INSTALLATION: John F. Kennedv Space Center

FY 2000 Estimate: $1,800,000

LOCATION OF PROJECT: Kennedy Space Center, Brevard County, Cape Canaveral, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning And Design	Construction	Total
Specific Construction Funding.	$108,000	$ ...	$108.000
Capitalized Investment	...	105,948,950	105,948,950
Total	$108,000	$105,948,950	$106,056,950

SUMMARY PURPOSE AND SCOPE:
This project restores the structural concrete of the launch pad surfaces to prevent the ingress of water, which accelerates deterioration of subbase materials and imbedded reinforcing steel. Pad B is required for Kennedy Space Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:
Pad **B's** concrete surface, slopes, and catacomb areas are over 30 years old. They are deteriorated with cracks, spalling. and broken sections that are unsafe for launch operations. The cracks in the pad surface permit water to leak into and weaken the underlying compacted fill. Launch vibration and hydrostatic pressure on the undermined slopes cause the concrete panels to crack further and break into pieces. Cracks in the pad surfaces allow acidic launch water to erode the pad rebar, which results in spalling failures of the catacomb ceiling and a structural weakening of the launch pad. The crawlerway grid path also has cracks in the substructure, which allows water to undermine the slopes and also erode the catacomb rebar and concrete.

IMPACT OF DELAY:
Failure to provide timely repair of the launch pad concrete surfaces will accelerate the rate of water infiltration and subsequent structural weakening, rapidly increasing the ultimate repair cost. If current conditions are not corrected soon, the potential will develop whereby the Shuttle could sustain foreign object damage during launch.

PROJECT DESCRIPTION:
This project repairs cracks in the launch pad concrete surfaces and replaces or repairs fractured and broken sections of concrete. The cracked areas of the pad slopes will be sealed, and the broken, raised or "bulged" portions will be removed. The underlying fill will be replaced and re-compacted. The subbase under the crawlerway slabs will be repaired. Cracks and joints on the pad surface will be sealed. The cracks in the concrete ceiling structure of the catacombs will be repaired.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Civil/Structural	LS	---	---	$1,800,000
Total				$1,800,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Restore Wall and Ceiling Integrity, Payload Changeout Room, Pad B

INSTALLATION: John F. Kennedy Space Center

FY 2000 Estimate: $2,300,000

LOCATION OF PROJECT: Kennedy Space Center, Brevard County, Cape Canaveral, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning And Design	Construction	Total
Specific Construction Funding	$184,460	---	$ 184,460
Capitalized Investment	---	$105,948,950	105,948,950
Total	$184,460	$105,948,950	$106,133,410

SUMMARY PURPOSE AND SCOPE:
The Launch Complex 39 Pad B Payload Changeout Room (PCR) was designed and built to provide a controlled environment for pre-flight services of space shuttle hardware. This project replaces damaged structures that allow contaminants to enter the PCR's controlled space. Project completion enhances the efficient and effective operation and maintenance of the PCR and supporting utilities. The PCR is required for Kennedy Space Center to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:
Contamination levels within the PCR have increased significantly. These contaminants enter the PCR via the weather damaged exterior walls and deteriorated access doors, which no longer maintain necessary pressurization levels. Friable insulation associated with mechanical components also contributes to the contamination. Current conditions will soon cause the payload processing environment to exceed acceptable limits for contamination and pressurization capability and therefore become a launch constraint.

IMPACT OF DELAY:
Failure to provide timely repair of the PCR structure and supporting mechanical systems will allow contamination levels to exceed acceptable limits. This will hinder space shuttle launch preparation and potentially cause launch delays. Operation and maintenance costs associated with keeping the deteriorated structure and mechanical components operating will dramatically increase.

PROJECT DESCRIPTION:
This project replaces damaged PCR wall panels; illuminates the access area within the PCR plenum, replaces the ceiling grid assembly, and replaces or eliminates various leaking access doors. The high efficiency particular air (HEPA) filter housing will be reconfigured to allow safer accessibility.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Civil/Structural	Lump Sum(LS)	--	---	$1,900,000
Mechanical	LS	---	---	200,000
Electrical	LS	---	---	200,000
Total				$2,300,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

PROJECT TITLE: Rehabilitate 480V Electrical Distribution Svstem, External Tank Manufacturing Building

INSTALLATION: Michoud Assemblv Facility

FY 2000 ESTIMATE: $1,800,000

LOCATION OF PROJECT: New Orleans, Orleans Parish, Louisiana

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding.	$656,000	$ 7,300,000	$ 7.956.000
Capitalized Investment	---	55,444,885	55,444,885
Total	$656,000	$62,744,885	$63,400,885

SUMMARY PURPOSE AND SCOPE:
This project rehabilitates and modifies the 480V electrical distribution system which supports critical External Tank (ET) manufacturing operations in the Barrel Mechanical Assembly, Harness and Tool Fabrication Areas, and the Thermal Protection System Development Area of the ET Manufacturing Building (103). This project specifically replaces the electrical distribution system associated with substations 4, 5, and 7B. It is required to restore quality and reliability to the electrical power system and avoid costly piecemeal repairs. Building 103 is required for the Michoud Assembly Facility to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:
The 480V electrical distribution system in Building 103 was originally installed in the 1940's. Exposed distribution feeders resulting from cracked insulation and "**spot**" overloads combine to create potential production shutdowns. Existing bus ducts are inaccessible

for maintenance. Feeder taps to fan houses lack over-current protection. Main distribution and sub-distribution panels and associated breakers are obsolete. Existing grounding does not meet the National Electric Code (NEC) or current design standards. An in-house long-range electrical plan and a subsequent A/E study recommend upgrade of the 480V power distribution system. This project corrects the unsafe and unreliable 480V electrical distribution system from substations 4, 5, and 7B to the Barrel Mechanical Assembly, Harness and Tool Fabrication Areas, and the Thermal Protection System Development Area of Building 103.

IMPACT OF DELAY:
Failure to rehabilitate exposed feeders, hot spots, and improper grounding will likely result in production shutdowns in the Barrel Mechanical Assembly, Harness and Tool Fabrication Areas, and the Thermal Protection System Development Area of the External Tank manufacturing operations.

PROJECT DESCRIPTION:
This project completes the systematic rehabilitation of older high-voltage systems in critical production areas of Building 103. It replaces transformers and switchgear, breakers and oil switches, and installs new main distribution and sub-distribution power panels. New electrical distribution feeders will be routed in cable trays for ease of maintenance. Electrical distribution circuits will be designed to eliminate the need for bus ducts. The new distribution system will be tied into substation switchgear and the old distribution system will be demolished.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Electrical	LS	---	---	$1,800,000
Total				$1,800,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

SUMMARY

SCIENCE, AERONAUTICS AND TECHNOLOGY

	Amount (Dollars)	Page No
Space Science:		
Construct Interferometry Development Laboratory (JPL)	2,500,000	MS 4-16
Earth Science:		
Restore Meterological Development Laboratory (GSFC)	1,000,000	MS 4-19
Aeronautics:		
Replace Fan Blades, National Full-Scale Aerodynamic Complex (ARC)	3,400,000	MS 4-21
Replace Main Drive for 14x22-Foot Subsonic Tunnel (LaRC)	7,300,000	MS 4-23
Total Science, Aeronautics, and Technology	14,200,000	

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Construct Optical Interferometrv Development Laboratory

INSTALLATION: Jet Propulsion Laboratory

FY 2000 CoF Estimate: $2,500,000

LOCATION OF PROJECT: La Canada - Flintridge, Los Angeles County, California

COGNIZANT HEADQUARTERS OFFICE: Office of Space Science

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project.

	Planning and Design	Construction	Total
Specific Construction Funding.	$400,000	$2,500,000	$2,900,000
Capitalized Investment	--	—	0
Total	$400,000	$2,500,000	$2,900,000

SUMMARY PURPOSE AND SCOPE:
For the first increment of this project. $2,500,000 was identified, and was initiated via **NASA's** FY 1999 Initial Operating Plan. This second and final increment completes construction of the Interferometry Development Laboratory. The facility &ill include I,330 square meters of laboratory areas plus additional space for restrooms. utility rooms, and an office. Laboratory areas include class 10,000 High Bay and Low Bay with adjacent non-clean support space for control electronics, computers. and equipment buildup. Highly sensitive instruments on optical tables require ground floor laboratories with vibration isolation pads in a clean environment. This facility will form the corner-piece of a three-building complex (two existing) which comprise the heart of optical interferometry **at** JPL.

PROJECT JUSTIFICATION:
The optical interferometry business base is growing rapidly, with a ground observatory project in development (Palomar), a second ground observatory and two major space missions just beginning (Keck, Deep Space 3, and Space Interferometry Mission) and a substantial supporting technology development program (Interferometry Technology Program). Other major projects are in the planning stage (e.g. Terrestrial Planet Finder). This building will provide urgently needed space to support projects from the **ORIGINS,** Advanced Technology and Mission Studies, and New Millennium programs.

Interferometry development laboratories and personnel are inefficiently scattered across JPL. Current accommodations can not meet the demands of the new flight programs that require significant new clean laboratory space by the end of 2001. The new space interferometer instruments will be large, typically tens of meters, or will have components distributed among multiple spacecraft, which must be demonstrated to work cooperatively as a single instrument. The new facility will be located near Buildings 171 and 306 to make available highly specialized Building 306 facilities such as supplementary clean and vibration-free space and for clustering purposes.

Vibration isolation pads (concrete blocks extending deep into the subsoil beneath the building) are needed to provide the base stability required for testing the interferometer systems to the required sub-nanometer pathlength and nanoradian pointing level. Building 306 is the only location with this capability and it is fully booked for many years with current flight projects, including the Thermal Emission Spectrometer and the Microwave Limb Sounder, as well as several smaller instrument tasks.

This project will allow the elimination of 26 trailers totaling 1209 square meters and the demolition of wood frame and stucco Building 11 (built in 1947) and Building 121 (built in 1952), totaling 900 square meters of antiquated, code deficient, maintenance intensive laboratory and office space.

IMPACT OF DELAY:
Delay in construction will cause cost increases due to inefficient use of people and testing work-around. The unavailability of suitable clean and vibration-free laboratory space will increase the flight performance risk and cause program schedule slips.

PROJECT DESCRIPTION:
This increment of work initiates construction of the Optical Interferometry Development Laboratory consisting of: one class 10,000 High Bay of approximately 458 square meter floor area and a height of 6 meters; one class 10,000 Low Bay of approximately 185 square meters; a ground (electronic) support area of approximately 134 square meters; and three class 100,000 development laboratories totaling approximately 219 square meters. The facility will also include a meeting room, office, and storage room totaling 52 square meters, and associated restrooms and circulation elements as required.

The facility will be located on Surveyor Road, across the street from Building 306. The site is currently occupied by a lot containing 26 wooden trailers, which will be demolished, making way for the modern, state of the art laboratory space.

The building will be a steel frame with concrete block and trusses, and a concrete base slab. Vibration isolation pads will be provided for optical tables in clean rooms. The exterior will be natural finish concrete block. Interior walls will be painted gypsum board, with epoxy paint on clean room walls. Ceilings will be grid supported faced tiles in the clean rooms. Heat, Ventilation and Air Conditioner (HVAC) systems will provide separate, zoned systems to the laboratories. High efficiency particular air (HEPA) filters and air showers will be provided in clean rooms. Utilities include clean instrument power; filtered nitrogen gas; and filtered, deionized, chilled cooling water.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Architectural/Structural/Sitework	LS	---	---	$1,570,000
Mechanical	LS	---	---	570,000
Electrical	LS	---	---	360,000
Total				$2,500,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Restore Meteorological Systems Development Laboratory

INSTALLATION: Goddard Space Flight Center

FY 2000 ESTIMATE: $1,000,000

LOCATION OF PROJECT: Greenbelt, Prince George's County, Maryland

COGNIZANT HEADQUARTERS OFFICE: Office of Earth Science

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning And Design	Construction	Total
Specific Construction Funding	$485,000	$4,000,000	$4,485,000
Capitalized Investment	---	4,947,107	4,947,107
Total	$485,000	$8,947,107	$9,432,107

SUMMARY PURPOSE AND SCOPE:
This project is the second and final increment to restore and upgrade various components of the Meteorological Systems Development Laboratory, Building 21. Areas affected include stairwells, egress paths, fire rating around laboratories, restrooms, mechanical systems, and electrical systems. The work will bring Building 21 into compliance with the Life Safety Code (1997), the Uniform Federal Accessibility Standards (1998), and the National Electrical Code (1996). Mechanical work will include asbestos removal. The first increment of this project was identified in the Agency's FY 1999 Initial Operating Plan in the amount of $4,000,000.

PROJECT JUSTIFICATION:
The building has been in service for 30 years. The existing systems have deteriorated and are beyond their useful life. It is essential to restore those components likely to fail to maintain reliable support of the Center's mission. The building is out of compliance with a variety of building, life safety, and accessibility codes; putting people, projects and equipment at risk. Operational requirements and budget constraints have severely strained system capabilities, increasing the risk of failure. This project corrects building problems that pose the greatest risk to safety, systems capacities, and reliable facility service.

IMPACT OF DELAY:
System breakdown could occur at any time, resulting in an emergency repair/replacement situation. The delay will increase operations and maintenance costs. Research critical to the GSFC mission is conducted in this building. Any unanticipated outage in the facility would seriously impact research operations.

PROJECT DESCRIPTION:
This project provides replacement of the existing variable air volume boxes, duct work, piping, diffusers and grilles, air-handling unit #4, electrical and controls upgrades, and some asbestos removal.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
General Requirements	LS	---	---	$ 35,000
Architectural/Structural	LS	---	---	150,000
Mechanical	LS	---	---	800,000
Electrical	LS	---	---	15,000
Total				$1,000,000

OTHER EQUIPMENT SUMMARY: None

FUTURE CoF ESTIMATED FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

PROJECT TITLE: Replace Fan Blades, National Full-Scale Aerodynamic Complex

INSTALLATION: Ames Research Center

FY 2000 Estimate: $3,400,000

LOCATION OF PROJECT: Moffett Field, Santa Clara County, California

COGNIZANT HEADQUARTERS OFFICE: Office of Aero-Space Technology

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$810,000	$2,000,000	$2,810,000
Capitalized Investment	---	---	---
Total	$810,000	$2,000,000	$2,810,000

SUMMARY PURPOSE AND SCOPE:
The scope of this project is to design, manufacture, and install new fan blades in the National Full-Scale Aerodynamic Complex (NFAC) at Ames Research Center. The NFAC is comprised of two large-scale wind tunnels that share a common fan drive system. The fan blades have developed significant cracking. An interim repair has been implemented until new blades can be procured.

PROJECT JUSTIFICATION:
The NFAC is a vital National facility that supports aerodynamic and aeroacoustic testing for research and development of fixed and rotary winged aircraft. The NFAC fan drive system was modified when the 80 X 120 wind tunnel leg was added in the late 1970's. Each of six fans was upgraded and the blades (15 per fan) were replace. The new blades were made from a laminated wood product called "Hydulignum". This material was used as the main structural component of the blades, while the leading and trailing edges and the outer tip region were made of spruce. The attachment of the blades to the fan drive was accomplished via a metal cuff that was threaded onto the root end of the blade. These blades continued in operation until 1996 when numerous cracks were discovered in the "Hydulignum" emanating from the root attachment area. An investigation revealed a higher dynamic loading on the blades than considered in the design. This caused the blades to vibrate at a rate 4 times greater than expected. The blades effectively reached their 40-year "fatigue life" after only 10 years of actual operation.

Temporary repairs consisting of injecting the cracks with high strength epoxy adhesive and wrapping the lower portion of the blade and steel cuff with a carbon composite material are complete. Based on fatigue tests, the temporary repairs will last for a maximum of 5-6 years. Permanent repairs must be accomplished to avoid shutdown of the facility.

IMPACT OF DELAY:
Temporary repairs have extended the safe operating life of the existing fan blades 5 years. Failure to replace these fan blades will result in increased cost, disruption, and delay to commercial and military aviation programs when the temporary repaired blades exceed their safe operating life. As currently planned, the project will have the new blades installed slightly before this time, ensuring minimum disruption of NFAC operations.

DESCRIPTION:
The scope of the total project is to design, manufacture, and install new composite fan blades in the National Full-Scale Aerodynamic Complex (NFAC) at Ames Research Center. New blades made from composite materials are the most viable method of replacing the temporary repaired blades. Composite blades will be substantially lighter than the current wood blades and have better damage tolerance characteristics. Design concepts for these new blades range from a traditional spar, rib, skin construction used in many of today's helicopter blades to a stiffened skin panel approach where stiffening elements are directly integrated into the outer skin assembly at the time of manufacture. The superior performance and increased durability of the new composite fan blades will ensure the operation of the National Full Scale Aerodynamic Complex for years to come.

Because of the wide variety of potential design solutions and manufacturers, prior year design funding was used for development of three conceptual designs. The FY 1999 funding increment is being used to complete the engineering after a concept is selected, develop structural prototypes, and initiate prototype testing and production. Follow-on funding in later fiscal years will complete the blade manufacture, delivery, and installation.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Manufacture New Blades	LS	---	---	$3,400,000
Total				$3,400,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: Future funding is needed in the amount of approximately $10,000,000 in order to complete this project. Without this funding, the blade replacement cannot be completed, risking facility shutdown if the temporary repair life is exceeded. When combined with FY 99 funding of $2,000,000, the total cost will be approximately $15,400,000.

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Replace Main Drive for 14x22-Foot Subsonic Tunnel

INSTALLATION: Langley Research Center

FY 2000 Estimate: $7,300,000

LOCATION OF PROJECT. Langley Research Center

COGNIZANT HEADQUARTERS OFFICE: Office of Aero-Space Technology

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding.	$175,000	$500,000	$675,000
Capitalized Investment	---	17.441.231	17.441.231
Total..	$175,000	$17,941,231	$18,116,231

SUMMARY PURPOSE AND SCOPE:
This project is the second and final increment to upgrade of the 14x22-Foot Subsonic Tunnel in Building 1212C. It provides a new main drive system, a set of fan blades. and modifications to the model preparation area. The project will provide improvements in drive performance, operational efficiencies. utility usage, operation and maintenance personnel requirements, and reduce life cycle costs. The first increment of this project, identified in the Agency's FY 1999 Initial Operating Plan in the amount of $500,000, provides for design of this design-build procurement.

PROJECT JUSTIFICATION:
The 14x22-Foot Subsonic Tunnel is used for low speed testing of powered and unpowered models of various fixed and rotary wing, civil and military aircraft. The tunnel became operational in 1970. The original drive system, with 1960s vintage drive technology. is still in place and utilizes custom control components that are no longer available. Spare parts have to be custom manufactured. The 14x22 Tunnel is heavily utilized. Closure of the LaRC 30x60-Foot Wind Tunnel has shifted additional experimental programs to the 14x22 Tunnel and requires accommodating added test hardware and increased operational efficiency. Its efficient operation is critical to the current Programs and will continue to be critical and heavily utilized for low speed requirements of future programs. This facility is sought and required by major customers such as Boeing North America, Lockheed Martin. Bell. Sikorsky. and the DOD.

IMPACT OF DELAY:
The frequency and severity of failures will increase due to significantly increased operational demands. A major failure of the drive system would cause an unplanned, two-year downtime and the consequences would be catastrophic to NASA's Program and commitments. The existing level of risk is unacceptable.

PROJECT DESCRIPTION:
The existing 6,650 horsepower (hp), three phase alternating current (ac) induction motor mounted in tandem with a 1,350 hp direct current motor will be replaced with an ac synchronous motor and controls having a maximum capability of 12,000 hp. This matches the existing drive capability at rated overload conditions. The existing motor-generator set, liquid rheostat, and associated controls will be removed. A set of nine fan blades plus one spare blade will be provided. Also included is a portable lift for model cart access, vacuum equipment to mitigate contamination of the models during air bearing operation, and modification of a structural support to facilitate cart movements.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Main Drive Equipment	LS	---	---	$4,800,000
Architectural/Civil/Structural	LS	---	---	400,000
Mechanical	LS	---	---	450,000
Electrical	LS	---	---	1,050,000
Fan Blades	LS	---	---	400,000
Model Prep Area Mods	LS	---	---	200,000
Total				$7,300,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None.

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMARY OF RESOURCE REQUIREMENTS

	FY 1998	FY 1999	FY 2000	Page Number
Discrete Projects	34,171	46,100	43,200	MS 4-26
Minor Revitalization	56,729	68,400	65,500	MS 4-53
Minor Construction	1,100	---	5,000	MS 4-59
Facility Planning and Design	19,000	14,000	19,200	MS 4-62
Deferred Major Maintenance	---	---	8,000	MS 4-66
Environmental Compliance and Restoration	11,400	40,000	40,100	MS 4-69
TOTAL	122,400	168,500	181,000	

Distribution of Program Amount by Installation	FY 1998	FY 1999	FY 2000
Johnson Space Center	4,907	13,990	15,500
Kennedy Space Center	17,109	28,190	30,800
Marshall Space Center	23,076	31,110	25,400
Stennis Space Center	8,828	10,600	11,000
Ames Research Center	5,520	13,600	12,800
Dryden Flight Research Center	6,867	4,520	6,550
Glenn Research Center	14,957	17,670	18,750
Langley Research Center	7,758	10,550	9,300
Goddard Space Flight Center	14,587	18,940	17,700
Jet Propulsion Laboratory	12,055	13,750	9,800
Various Locations	3,721	3,240	6,000
Headquarters	3,015	2,340	17,400
TOTAL	122,400	168,500	181,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

SUMMARY

MISSION SUPPORT

Mission Support Discrete Projects:	Amount (Dollars)	Page No
Restore Electrical Distribution System (ARC)	2,700,000	MS 4-27
Rehabilitate Main Hangar Building 4802 (DFRC)	2,900,000	MS 4-29
Rehabilitate High Voltage System (GRC)	7,600,000	MS 4-31
Repair Site Steam Distribution System (GSFC)	2,900,000	MS 4-33
Restore Chilled Water Distribution System (GSFC)	3,900,000	MS 4-35
Replace Hydrostatic Bearing Runner, 70 meter Antenna, Goldstone (JPL)	1,700,000	MS 4-37
Upgrade 70 meter Antenna Servo Drive, 70 meter Antenna Subnet (JPL)	3,400,000	MS 4-39
Rehabilitate Utility Tunnel Structure and Systems (JSC)	5,600,000	MS 4-41
Connect KSC to Cape Canaveral Air Station Wastewater Treatment Plant (KSC)	2,500,000	MS 4-43
Repair and Modernize HVAC System, Central Instrument Facility (KSC)	3,000,000	MS 4-45
Replace High Voltage Load Break Switches (KSC)	2,700,000	MS 4-47
Repair and Modernize HVAC and Electrical Systems, Bldg. 4201 (MSFC)	2,300,000	MS 4-49
Repair Roofs, Vehicle Component Supply Buildings (MAF)	2,000,000	MS 4-51
TOTAL DISCRETE PROJECTS	43,200,000	

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Restore Electrical Distribution System

INSTALLATION: Ames Research Center

FY 2000 Estimate: $2,700,000

LOCATION OF PROJECT: Moffett Field, Santa Clara County, California

COGNIZANT HEADQUARTERS OFFICE: Office of Aero-Space Technology

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$384,000	$ 2,200,000	$ 2,584,000
Capitalized Investment	---	9,795,543	9,795,543
Total	$384,000	$11,995,543	$12,379,543

SUMMARY PURPOSE AND SCOPE:
This project provides for repairs to the Center's primary electrical distribution system as part of a phased program to improve reliability. The existing relays in Substations N225B, N225, and the Arc Jet Facility will be replaced. Additionally, selected 115kV air switches, switchgear, and oil-filled circuit breakers will be replaced Centerwide.

PROJECT JUSTIFICATION:
The existing electrical system Centerwide at Ames is unreliable and in some cases unsafe. Ames has experienced a number of power interruptions emanating from varying sources, which has impacted critical research. Much of the electrical equipment such as the 115,000 volt oil circuit breakers, air operated switches, and metering systems were installed during or shortly after 1945. The oldest equipment at the Center is nearly 60 years old and much of the remaining equipment is 30 to 45 years old. Parts are not available for the majority of electrical equipment that is more than 40 years old.

The protective relays used in the Center are of electro-mechanical type. Electro-mechanical relays are still manufactured today by several manufacturers; however, they are rapidly being replaced by solid state (electronic) relays. Many of the oldest electro-mechanical relays at the Center can no longer be calibrated because of worn mechanical components. Replacement parts for many of those relays are no longer available.

IMPACT OF DELAY:
Power outages caused by electrical equipment failure will continue to disrupt mission-critical research across the Center and the ability of the Center to operate in an efficient manner and reduce costs. Power outages will continue to cost the Center in productivity, materials, and equipment.

PROJECT DESCRIPTION:
This project will enhance and improve the existing deteriorated systems and replace with new equipment such as: metering system, 115kV oil circuit breakers, 115kV air operated switches and protective relays. Approximately eight (8) 115kV air switches and eight (8) 115kV oil circuit breakers in the Substation N225 and N225B will be replaced. The existing protective relays in electrical Substations N225B and N225, for systems A, B, C, and D, will be replaced with new microprocessor based relays.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Replace Relays.	LS	---	---	$ 350,000
Replace Air Switches	LS	---	---	550,000
Replace Oil Breakers	LS	---	---	950,000
Replace Switch Gears	LS	---	---	850,000
Total				$2,700,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None, however, this project is part of a phased program to restore the electrical distribution system, on which a study is in progress. The full scope of restoration requirements are extensive, and may be in the $30 to $50 million dollar range.

, PROJECT TITLE: Rehabilitate Main Hangar Buildina 4802

INSTALLATION: Drvden Flight Research Center

FY 2000 CoF Estimate: $2,900,000

LOCATION OF PROJECT: Dryden Flight Research Center, Kern County, California

COGNIZANT HEADQUARTERS OFFICE: Office of Aero-Space Technology

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding.	$232,000	---	S 232,000
Capitalized Investment	--	$2.947.213	2.947.213
Tot.	$232,000	$2,947,213	$3,179,213

SUMMARY PURPOSE AND SCOPE:
The Main Hangar, the largest NASA-owned hangar at the Center, is essential to Dryden's mission as Lead Center for Flight Research. Although it received only limited upgrades since first being constructed, heavy usage and age results in it needing extensive rehabilitation. This project will rehabilitate the hangar to support modem aircraft and comply with current building, environmental. occupational health and safety. fire protection, disabled-employee access, and energy conservation codes and requirements.

PROJECT JUSTIFICATION:
Rehabilitation of the Main Hangar is essential to meet Dryden's flight research mission. Upgrading the hydraulics, shop air, and electrical systems will enable the hangar to support modem aircraft requirements, which are radically different from the requirements of aircraft existing in the 1950's. Ground support equipment must be moved in and out, and sometimes piecemeal repairs or modifications to the hangar have to be done, in order to meet the operational requirements of various aircraft. The massive steel and glass overhead doors at the north and south ends of Hangar B4802 are 30 high, 150 wide and weigh an

estimated five tons each. These doors must be refurbished to decrease risk of damage from seismic events and the resulting danger to personnel and research aircraft. The fire suppression system must be rehabilitated to decrease risk of fire damage to the hangar and its contents. Rehabilitation is long overdue to meet current building, environmental, occupational health and safety, fire protection, disabled-employee access, and energy conservation codes and requirements. Airtight double doors are needed to keep hazardous fumes from escaping into the adjoining office and laboratory building.

IMPACT OF DELAY:
Delaying this project puts personnel and aircraft at risk from falling or collapsing hangar doors should an earthquake occur at or near Dryden. Collapse of the massive hangar doors would endanger personnel and aircraft. Some of Dryden's research aircraft are one-of-a-kind and irreplaceable. Others are modified production aircraft with replacement values ranging from $5M to $50M each. Dryden will continue to operate inefficiently to meet the operational requirements of various aircraft. Energy and maintenance costs will continue to increase.

PROJECT DESCRIPTION:
This project will refurbish both hangar doors to meet seismic codes and standards. It will upgrade the heating, cooling, and electrical systems, including the installation of sixteen electrical stations. The central hydraulic and shop air systems will be refurbished. It will rehabilitate the fire suppression system (deluge valves) and provide airtight double entry doors into the adjoining office building. It will increase available hangar space by providing an addition to house ancillary activities now located within the hangar and rehabilitate the hangar to meet current building codes including environmental, occupational health and safety, fire protection, disabled-employee access, and energy conservation requirements. All new systems will allow for maximum operational flexibility within the hangar to meet requirements of current and future flight research aircraft.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Unit Quantity	Cost	Cost
Doors and Windows	LS	---	---	$ 462,000
Mechanical/Fire Protection	LS	---	---	766,000
Electrical	LS	---	---	629,000
Finishes & Specialties	LS	---	---	449,000
Masonry & Metals	LS	---	---	452,000
Thermal & Moisture Protection	LS	---	---	142,000
Total				$2,900,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Rehabilitate High Voltage System

INSTALLATION: John H. Glenn Research Center

FY 2000 ESTIMATE: $7,600,000

LOCATION OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Office of Aero-Space Technology

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$200,000	$ 17,300,000	$ 17,500,000
Capitalized Investment	---	32,400,000	32,400,000
Total	$200,000	$39,700,000	$39,900,000

SUMMARY PURPOSE AND SCOPE:
This project is the third of three construction phases that will rehabilitate and modify the Glenn Research Center's (GRC) existing High Voltage Power System. The project is required to assure continued reliability and safe electrical power supply at GRC. The system distributes power to all of the Center's aerospace research and development facilities, computer center, and the institutional facilities. The Agency's Enterprises and Center of Excellence missions support this project.

PROJECT JUSTIFICATION:
The high voltage power system provides power to all the aeronautics and aerospace R&D facilities to support major programs. It is over 50 years old, obsolete, and experiencing increased maintenance and emergency repairs each year. Current circuit breaker overloads and single point failures warn of a major failure that could result in a 6 to 12-month shutdown. Economic analysis indicates this project is the most cost-effective approach to maintain an operating system for the next 30 years.

IMPACT OF DELAY:
Unless the system is rehabilitated, failure rates currently being experienced are expected to increase. Major disruptions of electrical services, associated with single point failures, are also anticipated. These failures will result in the shutdown of critical research facilities and the programs they support for periods up to 12 months.

PROJECT DESCRIPTION:
This phase of the project replaces 34.5 kV overhead lines feeding Substation M from Substation A with underground lines from Substation K; replaces all overhead lines feeding Buildings 306, 307, 308, and 310 with underground lines from Substation N and Building 300 from substation M; replaces a 2.4 kV transformer at Building 300; replaces 34.5 kV transformer and cabling at Substation D and E; installs switchgear at Substation E; adds a 34.5 kV transformer at Substation H and Substation K; replaces miscellaneous substation breakers; provides control house improvements; and installs a solid state variable frequency drive starting system in Building 4.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Substation H modifications	LS	---	---	$1,400,000
Replacement of overhead lines	LS	---	---	1,800,000
Substation K modifications	LS	---	---	700,000
Substation D and e modifications	LS	---	---	1,500,000
Solid State Variable Frequency Starting System	LS	---	---	1,700,000
Miscellaneous Substations	LS	---	---	500,000
Total				$7,600,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None.

(

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Repair Site Steam Distribution System

INSTALLATION: Goddard Space Flight Center

FY 2000 Estimate: $2,900,000

LOCATION OF PROJECT: Greenbelt, Prince George's County, Maryland

COGNIZANT HEADQUARTERS OFFICE: Office Earth Science

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$392,000	$2,000,000	$2,392,000
Capitalized Investment	---	1,823,159	1,823,159
Total	$392,000	$3,823,159	$4,215,159

SUMMARY PURPOSE AND SCOPE:
This project is the second phase of a multiyear program to rehabilitate the central steam distribution system. The steam system has deteriorated with age and has become undersized due to substantial growth in buildings and related steam demand at Goddard Space Flight Center (GSFC).

PROJECT JUSTIFICATION:
The central steam distribution system was originally installed in the early 1960's and is at the end of its useful life. The added steam loads on the East Campus require significant upsizing of the main headers. Some condensate and high pressure drip lines have failed. The condensate is piped to a drain, resulting in waste of water, energy and treatment chemicals. This project will reduce operation and maintenance costs and enhances the reliability and maintainability of the site steam distribution system.

IMPACT OF DELAY:
A major failure could occur in the campus-wide steam distribution system, resulting in the loss of steam supply to several buildings. That would seriously impact critical spacecraft operations at GSFC. The delay will also increase operation and maintenance costs to keep the deteriorated system operational.

PROJECT DESCRIPTION:
This project provides for the replacement of major portions of the GSFC steam distribution system. Work includes replacing the south header, conducting utility designations/test holes in the construction area of the project, and other related construction items.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Replace south header	LS	---	---	$2,700,000
Utility designation/test holes	LS	---	---	80,000
Related construction items	LS	---	---	120,000
Total				$2,900,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None. However, funding will be required in future years to rehabilitate other elements of the steam distribution system.

PROJECT TITLE: Restore Chilled Water Distribution System

INSTALLATION: Goddard Space Flight Center

FY 2000 ESTIMATE: $3,900,000

LOCATION OF PROJECT: Greenbelt, Prince George's County, Maryland

COGNIZANT HEADQUARTERS OFFICE: Office of Earth Science

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$712,000	$9,116,781	$ 9,828,781
Capitalized Investment	---	11,597,139	11,597,139
Total	$712,000	$20,713,920	$21,425,920

SUMMARY PURPOSE AND SCOPE:
This project continues the restoration of major portions of the chilled water distribution system at Goddard Space Flight Center (GSFC). The project replaces underground piping and valves that are old, deteriorated, and undersized due to substantial increase in buildings and related chilled water demand at GSFC. Shutoff valves will be installed where needed.

PROJECT JUSTIFICATION:
GSFC has experienced serious operational problems with the central chilled water distribution system. The underground piping to be replaced is approximately 30 years old. The pipes and valves have badly deteriorated and leak substantially. Pipe sizes in several sections of the system are inadequate for existing, as well as future design flow rates. Many sections of piping do not have shutoff valves. The new lines will improve reliability and cooling conditions in several buildings, some of which do not have adequate redundancy in the event of a chilled water service failure.

IMPACT OF DELAY:
Delay of this project will result in continued leaking and failures due to old piping and increasing pressures. Some portions of the system will experience flow deficiencies unless pipe sizes are increased. As a result, several buildings will have inadequate chilled water quantities and air conditioning capacity causing shutdown of mission critical and technical support operations. The delay will also increase operation and maintenance costs required to keep the deteriorated system operational.

PROJECT DESCRIPTION:
The project provides for the replacement of major portions of the GSFC chilled water distribution system. This includes replacing the remainder of the northeast header from Building 7 to Building 16, the southwest header and supply lines to Buildings 6 and 11, and supply lines to Buildings 7 and 10; installing a branch to Building 22, a feed to Building 14, and connections to Building 5; and renting temporary chillers/diesel generators and other related construction items

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Unit Quantity	Cost	Cost
Replacement of remainder of northeast header from building 7 to building 16	LS	---	---	$860,000
Replacement of southwest header and supply lines to Bldgs 6 and 11	LS	---	---	1,224,000
Replacement of supply lines to Bldgs 7 and 10	LS	---	---	376,000
Rental of temporary chillers, diesel generators, other related construction costs	LS	---	---	120,000
Branch to Bldg. 22	LS	---	---	452,000
	LS	---	---	524,000
Feed to Bldg. 14	LS	---	---	118,000
Connections to Bldg. 5				
Miscellaneous related construction costs	LS	---	---	226,000
Total				$3,900,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None. However, funding will be required in future years to rehabilitate other elements of the chilled water distribution system.

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Replace Hydrostatic Bearing Runner, 70 meter Antenna

INSTALLATION: Jet Propulsion Laboratory

FY 2000 CoF Estimate: $1,700,000

LOCATION OF PROJECT: Goldstone Deep Space Communications Complex (GDSCC), Goldstone, California

COGNIZANT HEADQUARTERS OFFICE: Office of Space Science

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project.

	Planning and Design	Construction	Total
Specific Construction Funding	$136,000	---	$ 136,000
Capitalized Investment	---	$14,092,236	14,092,236
Total	$136,000	$14,092,236	$14,228,236

SUMMARY PURPOSE AND SCOPE:
This project replaces the multi-segment azimuth runner with a single piece, welded azimuth runner. The new design will reduce the oil leakage by eliminating the splices of the existing runner segments.

PROJECT JUSTIFICATION:
The present design of the runner includes eleven mechanical splices that allow oil to leak during antenna azimuth rotation. The oil penetrates and deteriorates the grout underneath the runner, causing loss of hydrostatic bearing film height. When the film height drops below acceptable limits, tracking stops immediately, regardless of the mission being supported, resulting in data loss. To avoid this adverse situation, at least ten hours of maintenance is required per week to continually shim the bearing runner to maintain minimum operational film height.

IMPACT OF DELAY:
Bearing shutdown causes unscheduled interruption of tracking support for major missions, such as Space VLBI, Ulysses, and Cassini resulting in the loss of valuable irretrievable data.

PROJECT DESCRIPTION:
This project replaces the azimuth runner on the 70 meter antenna at GDSCC. This includes lifting and supporting the entire antenna structure that rotates on the hydrostatic bearing and removing the existing runner and grout. A new, single-piece, welded runner design will be installed and the runner segments will be welded together in the field. Existing anchor and adjustment bolts will be used. The welded connections will be machined in-place and the entire bearing will be re-grouted and leveled to specification.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Runner	LS	---	---	$638,000
Jack Support	LS	---	---	462,000
Installation	LS	---	---	600,000
Total				$1,700,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Upgrade 70 meter Antenna Servo Drive, 70 meter Antenna Subnet

INSTALLATION: Jet Propulsion Laboratory

FY 2000 CoF Estimate: $3,400,000

LOCATION OF PROJECT: Goldstone, California; Canberra, Australia; and Madrid, Spain

COGNIZANT HEADQUARTERS OFFICE: Office of Space Science

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project.

	Planning and Design	Construction	Total
Specific Construction Funding	$272,000	---	$ 272,000
Capitalized Investment	---	$43,975,268	43,975,268
Total	$272,000	$43,975,268	$44,247,268

SUMMARY PURPOSE AND SCOPE:
The project provides for the replacement of the existing 35-year old servo drive hydraulic system used on the 70 meter antennas (DSS-14, 43, and 63) with current designs that are commercially available. Sequential implementation at the three complexes will minimize disruption of 70 meter Subnet tracking schedules. The new design will take advantage of advancements in hydraulic technology to optimize low speed performance for a smoother, more precise operation. This improvement will enhance antenna tracking and pointing performance.

PROJECT JUSTIFICATION:
The hydraulic components are no longer available from manufacturers and require costly custom machining to refurbish. The key components, such as motors and pumps, are rebuilt every two years and before any critical mission phase. The refurbishment lead times are increasing, jeopardizing antenna availability and increasing maintenance costs. Replacing obsolete equipment with commercial of-the-shelf-equipment will decrease maintenance costs and down time.

IMPACT OF DELAY:
If this project is not implemented, custom machining of components will continue to unnecessarily increase maintenance budgets. Because the components are unreliable, they pose a serious threat to antenna system availability and safety. The antennas' high level of reliability will be placed at risk. Missions affected by the unavailability of the antennas will suffer loss of irretrievable valuable data.

PROJECT DESCRIPTION:
The project will remove and replace the existing antenna servo drive hydraulics system; consisting of numerous high pressure pumps, motors, tachometers, accumulators, brakes and servo values; at each of the three 70 meter Antenna Subnet sites. The new equipment, as well as spare parts, is commercially available.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Hardware	LS	---	---	$3,100,000
Installation	LS	---	---	300,000
Total				$3,400,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

PROJECT TITLE: Rehabilitate Utilitv Tunnel Structure and Svstems

INSTALLATION: Lvndon B. Johnson Space Center

FY 2000 Estimate: $5,600,000

LOCATION OF PROJECT: Houston, Harris County, Texas

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding.	$421,055	$4,840,000	$5,261.055
Capitalized Investment	---	9,446,333	9,446,333
Total	$421,055	$14,286,333	$14,707,388

SUMMARY PURPOSE AND SCOPE:
This project is the third and final phase to rehabilitate the existing utility tunnel structure and systems. The work includes structural modifications, systems modifications, and provides safety features to meet Occupational Safety and Health Administration (OSHA) requirements. The utility tunnel is required for JSC to perform its assigned Agency roles and missions.

PROJECT JUSTIFICATION:
The utility tunnel system was originally constructed in 1962 to provide a protected passageway to carry utilities and services to Center buildings. The utility tunnel requires restoration in many areas to prevent water seepage through the structural concrete and to bring the tunnels into compliance with current safety regulations. The deteriorating conditions were confirmed as critical priorities during the Johnson Space Center (JSC) Facility Condition Assessment of 1992. Water infiltration into the tunnel structure is increasing in frequency and severity. The steam return/condensate system is rapidly approaching catastrophic failure condition. Numerous cable tray failures and inadequacies exist and hamper communications upgrades. Many valves in the chilled water system are beginning to exhibit wall failures from over-extended usage. Tunnel access and ventilation are inadequate for

personnel safety. Future major failures in the tunnel steam and chilled water systems are increasingly likely and would cause considerable disruption of services to buildings and potential hazard to operations personnel.

IMPACT OF DELAY:
If this project is not approved, the reliability and safety of the JSC utility tunnel and systems will continue to deteriorate and increase the risk of a catastrophic failure seriously disrupting mission operations.

PROJECT DESCRIPTION:
The work includes repairing and sealing of areas of water infiltration; correcting wall-section displacements; replacing concrete access sections; modifying substandard personnel access provisions; replacing steam condensate piping, components, and asbestos insulation; and replacing selected chilled water system valves and components. It upgrades the ventilation system; provides structural, cable, and cable tray modifications; and provides safety features to meet OSHA requirements.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Electrical Primary Distribution	LS	---	---	$3,900,000
Cable Tray Modifications	LS	---	---	600,000
Civil/Structural Modifications	LS	---	---	500,000
Mechanical Repairs	LS	---	---	600,000
Total				$5,600,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Connect KSC to Cape Canaveral Air Station Waste Water Treatment Plant

INSTALLATION: Kennedy Space Center

FY 2000 CoF Estimate: $2,500,000

LOCATION OF PROJECT: Merritt Island and Cape Canaveral, Brevard County, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$198,000	$ ---	$ 198,000
Capitalized Investment	---	784,241	784,241
Total	$198,000	$784,241	$982,241

SUMMARY PURPOSE AND SCOPE:
This project is an optimum revitalization investment that will eliminate high operation and maintenance costs and provide efficient and cost effective wastewater processing. It will provide the necessary pump stations and piping to connect KSC wastewater effluent distribution to the new Cape Canaveral Air Station (CCAS) wastewater treatment plant.

PROJECT JUSTIFICATION:
This project will eliminate environmental issues associated with obtaining permits for sewage treatment plants #1 & #4 drain fields. Consolidation of KSC sewage treatment will significantly reduce costs by eliminating the need for off-site sludge disposal, associated transportation, and operation and maintenance of existing aged systems.

IMPACT OF DELAY:
Delay of this project will significantly increase operating costs to transport and treat sewage off-site.

PROJECT DESCRIPTION:
This project will provide a new pump station to transfer effluent from STP-4 to STP-1 and a second pump station to transfer effluent from STP-1 approximately 9.8 kilometers to the CCAS treatment plant. The associated piping for the transfer lines, including approximately 300 meters of line to be bored under the Banana River Bridge, is included in the project. The CCAS percolation pond will be expanded to handle the wastewater transferred from KSC.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Pumping Stations, Transfer Lines	LS	---	---	$2,300,000
Expansion of CCAS Percolation Pond	LS	---	---	200,000
Total				$2,500,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

PROJECT TITLE: Repair and Modernize HVAC Svstem. Central Instrument Facility

INSTALLATION: Kennedv Space Center

FY 2000 Estimate: $3.000.000

LOCATION OF PROJECT: Merritt Island, Brevard County, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding.	$237,600	$950,000	$1,187,600
Capitalized Investment	---	10,145,291	10.145.291
Total	$237,600	$11,095,291	$11,332,891

SUMMARY PURPOSE AND SCOPE:
This project repairs and modernizes the heating, ventilating, and air conditioning (HVAC)system in the Central Instrument Facility (CIF). This facility requires rework of the HVAC air handling system to rehabilitate ductwork and install more efficient variable air volume and reheat systems. Present systems are old. obsolete. and in bad need of repair.

PROJECT JUSTIFICATION:
This HVAC system does not properly control the humidity level in the CIF. This is particularly critical in the calibration laboratories and other operational areas where humidity causes damage. The system is unreliable and inefficient. The air distribution ducting is old and needs to be replaced. Failure of the HVAC system would cause a lengthy outage in this building, leading to potential launch delays and extensive damage to computer and calibration equipment.

IMPACT OF DELAY:
Failure to implement this project will result in continued risk of HVAC failure. poor operational environment, and inefficient system operation. This wastes energy and increases costs. HVAC failure would cause a lengthy outage in the CIF leading to delay of missions, pose a safety hazard to operating personnel, and extensive damage to computer and calibration equipment.

PROJECT DESCRIPTION:
The project provides for rehabilitation of the HVAC system in the CIF. Work includes overhauling of ductwork; replacing obsolete air terminal induction units, air handling units, pumps, motors, air and water distribution piping; and installing an automated control system with electronic reheat to increase energy efficiency. Asbestos abatement is required.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Mechanical	LS	---	---	$1,250,000
Electrical	LS	---	---	800,000
Asbestos Abatement	LS	---	---	950,000
Total				$3,000,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

(

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Replace High Voltage Load Break Switches

INSTALLATION: Kennedy Space Center

FY 2000 CoF Estimate: **$2,700,000**

LOCATION OF PROJECT: Cape Canaveral. Brevard County, Florida

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDINC: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	S257.000	$3,100,000	$3,357,000
Capitalized Investment	---		31.162.000
Total	$257.000	$34.262.000	$34.519.000

SUMMARY PURPOSE AND SCOPE:
This project is the fourth and final phase of a comprehensive activity to replace all 15kV load break switches in the power distribution system at Kennedy Space Center. This project will replace high voltage manual type oil break switches to eliminate the explosive hazards associated with the operation and maintenance of oil-filled switches.

PROJECT JUSTIFICATION:
These obsolete switches have caused numerous explosions that could potentially injure or kill operating personnel. They are increasingly difficult and expensive to maintain. Replacement parts are no longer available from the manufacturer. These switches must be replaced for the safety of personnel and property.

IMPACT OF DELAY
Delay of this project will continue the use of obsolete oil break switches that are in violation of NASA safety standards and criteria. The possibility of a switch containing several gallons of oil exploding presents unacceptable risk of fire. injury, and environmental pollution.

PROJECT DESCRIPTION:
The manual type oil load break switches are to be replaced with newer style switches incorporating compression spring operators. Switch ratings will be increased from 400 amps to 600 amps with close-into-fault ratings of 40,000 amps. The system will be converted from oil to sulfurhexafloride (SF-6) as recommended by NASA's Safety, Reliability and Quality Assurance experts.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Switches and associated equipment	LS	---	---	$2,100,000
Installation	LS	---	---	600,000
Total				$2,700,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

(

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Repair and Modernize HVAC and Electrical Systems, Building 4201

INSTALLATION: George C. Marshall Space Flight Center

FY 2000 Estimate: $2,300,000

LOCATION OF PROJECT: Marshall Space Flight Center, Madison County, Alabama

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$182,000	---	$182,000
Capitalized Investment	---	$2,803,280	2,803,280
Total	$182,000	$2,803,280	$2,985,280

SUMMARY PURPOSE AND SCOPE:
This project is the first of three phases to repair and modernize old, deteriorated heating, ventilating, and air-conditioning (HVAC) equipment and electrical systems in Building 4201. The size, function and occupancy of this facility require this effort to be phased. This phase repairs and modernizes HVAC equipment, control systems, and electrical systems for the basement and floors 1, 2, and 3 of the building.

PROJECT JUSTIFICATION:
Building 4201, constructed in 1964, is a six-story steel frame structure with a basement and total gross area of 109,200 square feet. It is part of the Building 4200 complex, which is the central administrative campus for the Center, and houses many major project and program offices. The Building 4201 existing HVAC system and controls, along with the supporting electrical system, have been in use for over 30 years. Upgrading this building to modern office standards will provide adequate control of the building's climatic systems and reduce energy consumption. This project will help MSFC comply with an Executive Order, dated April 17, 1991, requiring all Federal agencies to reduce energy consumption per gross square foot 20 percent below 1985 consumption by the year 2000 and an additional 10 percent by 2005.

IMPACT OF DELAY:
If this project is delayed Building 4201 will continue to experience excessive maintenance costs and high energy consumption. MSFC will not be able to comply with the Executive Order. Complaints about the unsatisfactory environment in the building will increase and lower employee morale.

PROJECT DESCRIPTION:
This project will repair and modernize old and deteriorated HVAC equipment, control systems, and electrical systems for the basement and the first, second and third floors of Building 4201. The work includes replacing the control systems on more than 108 mixing boxes. The existing air-handlers will be left as they are. Heating coils, cooling coils, dampers, and fan impellers will be replaced. The existing mixing boxes will be upgraded with new direct digital control hardware and interface with the Utility Control System. The new control configuration will enable the interior mixing boxes to function as variable-air-volume units while the exterior mixing boxes continue to operate as constant-volume-units. Office lighting will be replaced with energy efficient lighting. An engineering study is being conducted to determine the extent of mechanical modifications required in Building 4201.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Architectural	SF	---	---	$184,000
Mechanical	SF	---	---	1,403,000
Electrical	SF	---	---	713,000
Total				$2,300,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: Future funding requirements will be determined based upon an engineering study currently under contract.

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Repair Roofs, Vehicle Component Supply Buildings

INSTALLATION: Michoud Assembly Facility

FY 2000 ESTIMATE: $2,000,000

LOCATION OF PROJECT: New Orleans, Orleans Parish, Louisiana

COGNIZANT HEADQUARTERS OFFICE: Office of Space Flight

FY 1999 AND PRIOR YEARS FUNDING: The following prior years funding is related to this project:

	Planning and Design	Construction	Total
Specific Construction Funding	$83,000	$ ---	$ 83,000
Capitalized Investment	---	3,890,986	3,890,986
Total	$83,000	$3,890,986	$3,973,986

SUMMARY PURPOSE AND SCOPE:
This project will replace 2,005 squares of roofing on Building 220 and 254 squares of roofing on Building 104. Repairs to the 220 and 104 roofs are necessary to prevent further structural deterioration that may result in damage to flight hardware, equipment, and supplies.

PROJECT JUSTIFICATION:
The Building 220 roof was installed in 1966 and the Building 104 roof was installed in 1943. Both roofs have exceeded their 20-year design life. The roof on Building 220 (which contains flight hardware and tooling components) has bare spots in the gravel, soft spots/blisters in the membrane, rust, open laps, felt deterioration, leaks in several areas, and inadequate lightning protection. The roof on Building 104 (which contains the battery shop and maintenance equipment) has bare spots in the gravel, "alligatoring"

/cracking, deterioration, blister, rust, and inadequate lightning protection. Both roofs are in poor condition and recommended for replacement in the 1990 Long-Range Roofing Inspection/Assessment plan.

IMPACT OF DELAY:
Failure to repair roofs will result in continued deterioration, which may lead to structural, flight hardware, and equipment/supplies damage.

PROJECT DESCRIPTION:
The existing built-up roofs will be removed and replaced with a new roofing system of 4-ply gravel that has reflective coating. The Building 220 roof needs 2,005 squares and the Building 104 roof needs 254 squares. Rust will be removed from all metal flashings, copings, and other ferrous material. Lightning protection will be provided on both buildings.

FY 2000 PROJECT COST ESTIMATE:

	Unit of Measure	Quantity	Unit Cost	Cost
Architectural/Structural.	LS	---	---	$1,850,000
Electrical/Mechanical.	LS	---	---	150,000
Total				$2,000,000

OTHER EQUIPMENT SUMMARY: None

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED TO COMPLETE THIS PROJECT: None

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMMARY

MINOR REVITALIZATION

Location:

	Amount
Ames Research Center	$ 8,050,000
Dryden Flight Research Center	2,500,000
Glenn Research Center	7,500,000
Goddard Space Flight Center	5,300,000
Jet Propulsion Laboratory	3,900,000
Johnson Space Center	4,200,000
Kennedy Space Center	6,600,000
Langley Research Center	7,950,000
Marshall Space Flight Center	7,050,000
Michoud Assembly Facility	2,750,000
Stennis Space Center	6,100,000
Wallops Flight Facility	2,700,000
Various Locations	900,000
Total	$65,500,000

PROJECT TITLE: Minor Revitalization of Facilities, Not in Excess of $1,500,000 Per Project

INSTALLATION: Various Locations

FY 2000 Estimate: $65,500,000

FY 1998: $56,729,000 FY 1999: $68,400,000

COGNIZANT INSTALLATIONS/LOCATIONS OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Office of Management Systems and Facilities

SUMMARY PURPOSE AND SCOPE:
These resources provide for revitalization of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. The request includes facility revitalization needs for FY 2000 that are greater than $500 thousand but not in excess of $1.5 million per project. Revitalization projects provide for the repair, modernization, and/or upgrade of facilities and collateral equipment. Repair and modernization projects restore facilities and components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability. Repair and modernization work includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown and major preventive measures that are normally accomplished on a cyclic schedule. Upgrade projects may include some restoration of current functional capability but also includes enhancement of the condition of a facility so that it can more effectively accomplish its designated purpose or increase its functional capability. The facilities being revitalized in this program are expected to remain active in the long term and are consistent with current and anticipated Agency roles and missions.

PROJECT JUSTIFICATION:
NASA is now experiencing "block obsolescence" where substantial portions of the agency's facilities have been in use for over 30 years. Repair costs for mechanical and electrical systems in a typical building are almost three times higher after system operations exceed 15-20 years than they are during the initial years. Many electrical and mechanical components reach the end of their serviceable or economic life at the 20-year point and should be replaced in the interest of long-term economy. Continued piecemeal repair of these components is more costly in the long run than replacement at the end of the economic life of the original components. Approximately 90 percent of NASA's physical plant has been in service for over 25 years.

The NASA physical plant has a capital investment of $5.8 billion and has a current replacement value of more than $17 billion. A continuing program of revitalization of these facilities is required to accomplish the following:

a. Protect the capital investment in these facilities by minimizing the cumulative effects of wear and deterioration.
b. Ensure that these facilities are continuously available and that they operate at peak efficiency.
c. Improve the capabilities and usefulness of these facilities and thereby mitigate the effects of obsolescence.
d. Provide a better and safer environment for all personnel.
e. Avoid significantly greater future repair costs.

This program includes revitalization work exceeding $500 thousand per project. Projects $500 thousand and less in magnitude are normally accomplished by routine day-to-day facility maintenance and repair activities provided for in Human Space Flight; Science, Aeronautics and Technology; and Mission Support appropriations. Projects estimated to cost more than $1.5 million are included as separate discrete projects in the budget request.

PROJECT DESCRIPTION:
Proposed projects for FY 2000 totaling $65.5 million are identified under "MINOR REVITALIZATION PROJECT COST ESTIMATE". The projects that comprise this request are of the highest priority based on relative urgency and expected return on investment. Deferral of this mission-essential work would adversely impact the availability of critical facilities and program schedules. The titles of the projects are designed to identify the primary intent of each project and may not always capture the entire scope or description of each project. Also, during the year, some rearrangement of priorities may be necessary which may force a change in some of the items to be accomplished. Any such changes, however, will be accomplished within total available revitalization resources.

MINOR REVITALIZATION PROJECT COST ESTIMATE:

A. Ames Research Center (ARC)	$8,050,000
1. Repair and Modernize 60 Megawatt Direct Current Power Supply, Thermal Protection Lab [N234A]	1,400,000
2. Modify/Add to Building 566 for Ames Child Care Facility	1,400,000
3. Repairs to Unitary Plan Wind Tunnel [N227]	1,200,000
4. Repair and Modify Shop and Model Preparation Areas, Model Construction Facility [N246]	1,200,000
5. Repair High Pressure Systems	800,000
6. Repair and Modernize Fire Suppression and Alarm Systems, Research Support Facility [N213]	600,000
7. Repair and Modernize Building, Life Sciences Research Laboratory [239A]	550,000
8. Upgrade to 8-cm Arc Jet Heaters, Arc Jet Laboratory [N238]	900,000
B. Dryden Flight Research Center (DFRC)	$2,500,000
1. Seismic Repair, Integrated Test Facility [4840]	800,000
2. Repair, Modernize, and Upgrade Infrastructure of Research, Development, and Test Facility [4800]	1,000,000
3. Repair and Modify Communications Ductbank Infrastructure	700,000

C. Glenn Research Center (GRC)	$7,500,000
1. Upgrades to Safety, Security, and Information Infrastructure, Plum Brook Station	800,000
2. Repair and Modernize Mechanical and Electrical Systems, Chemical Laboratory [6]	900,000
3. Repair Roof of Engine Research Building Complex [5, 23, 38]	900,000
4. Repair and Modernize Electrical and Mechanical Systems [51, 106]	1,100,000
5. Repair Sanitary Sewer Systems	800,000
6. Repair and Modernize Cryogenic Services Building [83]	550,000
7. Repair Underpass Road Bridges	850,000
8. Repair and Modernize Mechanical and Electrical Systems in 8x6 Subsonic Wind Tunnel Office [54]	900,000
9. Repair and Modernize Main Cafeteria [15]	700,000
D. Goddard Space Flight Center (GSFC)	$5,300,000
1. Repair and Modernize Fire Protection and Domestic Water System, Area 200	800,000
2. Repair and Modernize Heating, Ventilation, and Air Conditioning Systems [22]	850,000
3. Repair High Voltage Electrical System, Various Buildings	850,000
4. Repair Roofs, Various Buildings	850,000
5. Repair and Modernize Heating, Ventilation, and Air Conditioning Systems [25]	1,250,000
6. Consolidate and Upgrade Applied Engineering and Technology Directorate Labs [5, 11]	700,000
E. Jet Propulsion Laboratory (JPL)	$3,900,000
1. Install Uninterruptible Power Supply, Space Flight Support Facility [264]	850,000
2. Modify Fire Alarm Systems, Various Buildings	700,000
3. Modify Air Handling and Controls, Earth and Space Science Laboratory [300]	1,500,000
4. Modernize 1st and 2nd Floors, Information Systems Development Building [126]	850,000
F. Johnson Space Center (JSC)	$3,350,000
1. Repair and Upgrade Fire Alarm and Sprinkler Systems, Various Facilities	1,150,000
2. Replace 12 kV Switches, Various Facilities	950,000
3. Repair and Upgrade Fire Alarm System, Emergency Operations Center [30]	700,000
4. Repair Propulsion Area Water Lines @ White Sands Test Facility [300, 400 Areas]	850,000
5. Repair and Modernize Mission Simulation Development Facility [35]	550,000
G. Kennedy Space Center (KSC)	$6,600,000
1. Upgrade Facilities for Disabled Access, Various Facilities	600,000
2. Repair and Upgrade Roads and Paved Areas	900,000
3. Replace Feeder Cables 608 and 614, Various Locations	550,000

4. Repair and Modernize Ground Support Equipment Development Laboratory	950,000
5. Repair and Modernize HVAC, Thermal Protection Systems Facility	900,000
6. Safety Modifications to Pad B Hinge Column Crossover	500,000
7. Revitalize Secondary Power Systems, LC-39 Industrial Area	900,000
8. Modify Helium Gasification Complex to Provide Storage Capabilities	1,300,000
H. Langley Research Center (LaRC)	$7,950,000
1. Modify Building 647 to Provide Additional Model Preparation Area	1,100,000
2. Performance Modifications to 8-Foot High Temperature Tunnel Combuster Facility [1265]	1,400,000
3. Replace Heater Controls, 31-inch Mach 10 Tunnel [1251A]	1,425,000
4. Repair and Modernize Interior of Information Media Center	1,175,000
5. Repair and Modernize Office Building [1192C]	1,425,000
6. Upgrade Control and Fuel Systems, Arc-Heated Scramjet Test Facility [1247B]	1,425,000
I. Marshall Space Flight Center (MSFC)	$7,050,000
1. Safety Modifications to Overhead Cranes	600,000
2. Repair and Modernize Fire Alarm Systems, Various Buildings	1,000,000
3. Repair and Modernize Electrical and Mechanical Systems, Developmental Process Lab [4711]	1,100,000
4. Replace Roofs of Structural Dynamics and Thermal Vacuum Laboratory [4619]	1,250,000
5. Repairs to South Tank Line, Surface Treatment Facility [4760]	1,500,000
6. Repair and Modernize Electrical and Mechanical Systems, Structures and Mechanics Lab [4619]	900,000
7. Convert 20-Foot Vacuum Chamber to Cryopumps, Environmental Test Facility [4619]	700,000
J. Michoud Assembly Facility (MAF)	$2,750,000
1. Repair Dehumidifiers Cells C&H, Vertical Assembly Building/High Bay Addition Building [110/114]	900,000
2. Repair and Modernize Sterilizer System, Systems Engineering Building [130]	900,000
3. Replace Two Critical Chillers, Vertical Assembly Building/Acceptance and Prep Building [110/420]	950,000
K. Stennis Space Center (SSC)	$6,100,000
1. Repairs to Shuttle Parkway	600,000
2. Repair and Modernize Energy Management Control System, Various Facilities	700,000
3. Repair and Modernize Mechanical Systems, Data Acquisition Facility [4995]	1,100,000
4. Repairs and Modifications to 13.8 KV Electrical Distribution System, Centerwide	1,200,000
5. Repair Marine Mooring Dolphins	550,000
6. Increase Capacity and Expand GH2/GN2 High Pressure Distribution System	1,400,000
7. Repair and Modernize Secondary Power Systems, Various Facilities	550,000

L. Wallops Flight Facility (WFF)	$2,700,000
1. Repair Communications Ductbank	650,000
2. Repair Storm Drainage System, Mainbase Area	800,000
3. Repair and Modernize Radar Facilities [U-25, U-30]	550,000
4. Repair and Modernize Payloads Development and Integration Facility [F-8]	700,000
M. Various Locations	$900,000
1. Replace Hydraulic Drive, 26M Antenna [DSS-16]	900,000
Total Minor Revitalization	$65,500,000

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED:
Annual funding will be required for continuing minor revitalization needs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMMARY

MINOR CONSTRUCTION

Location:

	Amount
Various Locations	$ 5,000,000
Total	$ 5,000,000

PROJECT TITLE: Minor Construction of New Facilities and Additions to Existing Facilities Not in Excess of $1,500,000 Per Project

INSTALLATION: Various Locations

FY 2000 Estimate: $5,000,000

FY 1998: $1,100,000 FY 1999: $0

SUMMARY PURPOSE AND SCOPE:
These resources will provide for minor facility construction at NASA field installations. Each project in this program is estimated to cost no more than $1.5 million and involves either the construction of new facilities or additions to existing facilities.

PROJECT JUSTIFICATION:
The FY 2000 $5.0 million Minor Construction program will primarily replace substandard facilities in cases where it is more economical to demolish and rebuild than it is to restore. In selected cases, additional square footage may be built when there are compelling reasons to support new or specialized requirements of a nature that cannot be provided for using existing facilities. Included in this latter category are technical, programmatic, and institutional projects that are essential to the accomplishment of an installation's mission objectives.

PROJECT DESCRIPTION:
Included in the FY 2000 Minor Construction Program are those facility projects for institutional or technical facility needs that could be fully identified at the time of submission of this budget estimate. Items of work totaling $5.0 million are included in this resource request. Projects were selected on the basis of the relative urgency of each item and the expected return on the investment. During the course of the year, the revision of priorities may require changes in some of the items to be accomplished. Such changes will be accommodated within the total resources allocated. Most of these projects replace old and dilapidated railroad box cars, trailers, and other modular facilities that do not meet current occupational health and safety standards, and which no longer satisfy user functional requirements. Poor ventilation and leaky walls and roofs make the interior barely habitable. When weather conditions increase the probability of lightning activity, occupants of these facilities must evacuate them due to lack of lightning protection and the associated fire hazard. These facilities must also be evacuated in times of tornado watches and warnings, and high wind alerts. This is a frequent and very disruptive routine that impacts productivity and employee morale. It results in higher costs and increased risk of human error. Life cycle analyses support replacing these facilities with new permanent buildings rather than trying to repair the existing ones.

MINOR CONSTRUCTION PROJECT COST ESTIMATE:

A. Kennedy Space Center (KSC)	$5,000,000
1. Construct Replacement Housing for Orbiter Processing Facility (OPF) Hazardous Ops Personnel	550,000
2. Construct Replacement Housing for Shuttle Landing Facility (SLF) Landing Aids Ops Personnel	1,000,000
3. Construct Replacement Housing for Pad A LOX/LH2 Operations Personnel	1,000,000
4. Construct Replacement Housing for Payload Processing Support Personnel	800,000
5. Construct Replacement of Building 21900 Operations Support Space	900,000
6. Construct Addition to LC-39 News Facility	750,000
Total Minor Construction	$5,000,000

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED: Annual funding will be required for continuing minor construction needs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMMARY

FACILITY PLANNING AND DESIGN

	Amount
Master Planning	$ 400,000
Sustaining Engineering Support	1,000,000
Project Planning and Design Activities	17,800,000
Total	$19,200,000

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATE

PROJECT TITLE: Facility Planning and Design

FY 2000 Estimate: $19,200,000

FY 1998: $19,000,000

FY 1999: $14,000,000

These funds are required to provide for advance planning and design activities; special engineering studies; facility engineering research; preliminary engineering efforts required to initiate design-build projects; the preparation of final designs, construction plans, specifications, and associated cost estimates; and participation in facilities related professional engineering associations and organizations as follows:

A. Master Planning — $400,000

Provides for updating, developing and automating existing field installation master plans. This effort includes facility studies, site investigations, and analyses of utility systems. The existing utility and civil drawings will be converted into a highly detailed electronic database using computer-aided-design (CAD) systems. Topographical features from original drawings will be merged electronically to create individual area maps or an entire center map. The master plan documents will be updated to reflect as-built conditions and to graphically represent the 5-year facility plan baseline for future development.

The NASA field center master plans are periodically updated. The master plans are essential as reference documents for land use planning, identification of physical relationships of facilities, and proper orientation and arrangement of facilities. The updates reflect as-built condition of facilities and utility systems with emphasis on changes caused by recent facility construction and modifications.

B. Sustaining Engineering Support — $1,000,000

Provisions for facility studies and specific engineering support continue in importance as evidenced in recent years. These efforts are important due to changing trends in construction equipment, materials, and fuels; the operation and maintenance costs for the physical plant; and energy conservation and efficiency. The following items are included in the FY 2000 requirements:

1. Value Engineering, and Design and Construction Management Studies
Provides for critically important studies to improve the quality and cost effectiveness of NASA's facility components and construction practices, and to ensure that developing technology and industry best practices are incorporated into the agency's construction program. Also provides services necessary to predict and validate facility costs to aid in resources planning.

2. Facility Operation and Maintenance Studies

Provides for studies and engineering support where not otherwise provided for, at NASA field installations relative to functional management of maintenance, automated maintenance management systems, and facilities condition assessments. Included in this activity are field surveys to be conducted at selected NASA field installations to evaluate the effectiveness and efficiency of the operations and maintenance management activities, and to identify possible improvements in productivity.

3. Facilities Utilization Analyses
Provides for the analyses of agencywide facilities utilization data covering (1) office and other types of building space; (2) designated major technical facilities; and (3) special studies comparing the utilization of technical facilities which are similar in type or capability, such as wind tunnels. Such analyses provide for (1) insights into and development of better methods of identifying underutilized facilities; (2) improved techniques to quantify level of facilities use; (3) actions to improve facilities utilization; and (4) recommendations regarding consolidation/closure of Agency facilities.

4. Facilities Management Systems
Provides for continued engineering support for the technical updating of NASA's master text construction specifications to reflect the use of new materials, state-of-the-art construction techniques and current references to building codes and safety standards. Also provides engineering support for the Major Facilities Inventory, the Real Property Database and the Facilities Utilization Database systems.

5. Capital Leveraging Research Activities
Provides for modest participation in facilities related professional engineering associations, institutes, and organizations established to bring together major facility owners, contractors, and academia in proven research and study efforts to improve the quality and cost effectiveness of facilities engineering management practices for member organizations. Such organizations include, but are not limited to, the Federal Facilities Council of the National Research Council, National Institute of Building Sciences, and the Construction Industry Institute. This also provides for independent research activities to address facility problems unique to NASA.

C. Project Planning and Design Activities — $17,800,000

1. Preliminary Engineering Reports (PERs) — (700,000)
This estimate provides for preparation of PERs, investigations, project studies and other pre-project planning activities related to proposed facility projects in the FY 2002 and FY 2003 Construction of Facilities programs. These reports are required to permit the early and timely development of the most suitable project to meet the stated programmatic and functional needs. Reports provide basic data, cost estimates and schedules relating to future budgetary proposals.

2. Related Special Engineering Support — (400,000)
This estimate provides for investigations and project studies related to proposed facility projects to be included in the subsequent Construction of Facilities programs. Such studies involve documentation and validation of 'as-built' conditions, survey/study of present condition of such items as roofing and cooling towers, utility plant condition and operational modes, and other similar studies. These studies are required to allow for the timely development of projects to meet the stated functional needs and to provide basic data, cost estimates and schedules for related future budgetary proposals.

3. Final Design (16,700,000)

The amount requested will provide for the preparation of designs, plans, drawings, and specifications necessary for the accomplishment of construction projects. Also provides technical and engineering support analyses, designs, and reviews required to verify, confirm and ensure suitability of construction designs within the project cost estimates. This work is associated with construction proposed for the FY 2002 program, estimated to cost $110 to $120 million, and with changes to projects proposed for the FY 2001 program. The goal is to obtain better facilities on line earlier at a lower cost. An additional $8 million has been provided for work required to accomplish the increase in construction anticipated in FY 2001 and FY 2002, estimated to cost $170 to $190 million, as determined by the Agency's core capabilities study currently underway.

Total Facility Planning and Design $19,200,000

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONSTRUCTION OF FACILITIES

FISCAL YEAR 2000 ESTIMATES

SUMMARY

DEFERRED MAINTENANCE

Location:

Location	Amount
Various Locations	$ 8,000,000
Total	$ 8,000,000

CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

PROJECT TITLE: Deferred Maintenance of Facilities, Not in Excess of $500,000 Per Project or Unlimited for Maintenance Work

INSTALLATION: Various Locations

FY 2000 Estimate: $8,000,000

FY 1998: $0

FY 1999: $0

COGNIZANT INSTALLATIONS/LOCATIONS OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Office of Management Systems and Facilities

SUMMARY PURPOSE AND SCOPE:
These resources provide for projects to partially mitigate the growth in deferred maintenance and repair of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. The request includes facility maintenance and repair needs for FY 2000 that are up to $500 thousand per repair and unlimited for maintenance work. These maintenance and repair activities include work to provide for the repair and/or overhaul of facilities and collateral equipment. Repairs and/or overhauls restore facilities and components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability, and level of safety. This work includes the substantially equivalent replacement of utility system components and collateral equipment necessitated by incipient or actual breakdown, major preventive measures that are normally accomplished on a cyclic schedule, restoration of current functional capability, and upgrades to comply with current codes, safety standards and other commercial practices so the facility can effectively accomplish its originally designated purpose and functional capabilities. The facilities being repaired and overhauled in this program are expected to remain active in the long term and are consistent with current and anticipated Agency roles and missions.

PROJECT JUSTIFCATION:
NASA is experiencing annual growth in deferred maintenance and repair due to severely constrained resources. Accelerating deterioration potentially threatens safety and NASA's mission. This backlog of maintenance covers a substantial portion of the agency's facilities, which have been in use for over 40 years. The NASA physical plant has a capital investment book value of $5.8

billion and has a current replacement value of more than $17 billion. An adequate continuing program of routine maintenance and repair of these facilities is required to accomplish the following:

a. Protect the capital investment in these facilities by minimizing the cumulative effects of wear and deterioration.
b. Ensure that these facilities are continuously available to support NASA's mission and that they operate at peak efficiency.
c. Maintain the originally designed level of safety and reliability that the facilities were constructed to.
d. Avoid significantly greater future repair costs that result from facility failures.
e. Minimize the growth of additional unfunded backlog of deferred maintenance and repair.

This routine maintenance and repair work costing $500 thousand and less for repair or unlimited for maintenance is normally accomplished by routine day-to-day facility maintenance and repair activities provided for in Human Space Flight; Science, Aeronautics and Technology; and Mission Support appropriations.

PROJECT DESCRIPTION:
The highest priority deferred work totaling $8 million will be identified based on the findings of the Agency's Core Capabilities Assessment currently underway. The deferred maintenance and repair work that is to be completed by this request will be the highest priority based on safety, relative urgency, and expected return on investment. Continued deferral of this mission-essential work would adversely impact the availability of critical facilities and program schedules.

FUTURE ESTIMATED CONSTRUCTION FUNDING REQUIRED: Additional funding will be necessary to ameliorate the present backlog of deferred facilities maintenance and repair. Funding requirements will be based on the findings of the Agency's Core Capabilities Assessment currently underway.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CONSTRUCTION OF FACILITIES
FISCAL YEAR 2000 ESTIMATES

SUMMARY

ENVIRONMENTAL COMPLIANCE AND RESTORATION (ECR) PROGRAM

Summary of Project Amounts by Location:	Amount
Dryden Flight Research Center	600,000
Glenn Research Center	2,550,000
Jet Propulsion Laboratory	4,700,000
Johnson Space Center	1,300,000
Kennedy Space Center	6,020,000
Marshall Space Flight Center	6,825,000
Michoud Assembly Facility	1,250,000
Stennis Space Center	3,600,000
Wallops Flight Facility	1,100,000
White Sands Test Facility	3,200,000
Studies, Assessments, and Investigations; Plans; Designs; Sampling, Monitoring and Operation of Remedial Treatment Processes; Related Engineering and Program Support	8,955,000
Total	$40,100,000

PROJECT **TITLE:** **Environmental Compliance and Restoration (ECR) Program**

INSTALLATION: Various Locations

FY 2000 Estimate: $40,100,000

FY 1998: $11,400,000 **FY 1999: $40,000,000**

COGNIZANT INSTALLATIONS/LOCATIONS OF PROJECT: Various Locations

COGNIZANT HEADQUARTERS OFFICE: Office of Management Systems and Facilities - Environmental Management Division

SUMMARY PURPOSE AND SCOPE:
These resources will provide for environmental activities necessary for compliance with environmental measures including environmental program initiatives. The purpose of the ECR Program is to enable NASA to comply with environmental statutory and regulatory requirements and standards. orders, regulatory and cooperative agreements, and support of environmental program initiatives. The Program focuses our efforts into the following principal areas: compliance, remediation. restoration, and prevention. Within this framework, compliance with environmental requirements is performed, while implementing remedlation at previously contaminated sites, and promoting the identification of pollution prevention and restoration activities. The resources authorized and appropriated pursuant to this program may not be applied to other activities. Program activities include projects, studies, assessments. investigations. plans. designs, related engineering, program support, and sampling, monitoring, and operation of remedial treatment processes as part of the remediation/cleanup measures. These activities will be performed at NASA installations, Government-owned industrial plants supporting NASA activities, and other locations where NASA operations have contributed to environmental problems and NASA is obligated to contribute to cleanup costs. In addition, these resources will be used to provide for regulatory agency oversight costs, to acquire land if necessary to implement environmental compliance and restoration measures, and to perform studies, assessments, and activities in support of functional leadership initiatives related to the environmental program. Examples of activities included in the program are: prescribed remedial investigations and feasibility studies required by environmental laws and regulations: performance of environmental restoration. hazardous waste removal and disposal, remediation/cleanups, closures. and environmental compliance actions: studies, investigations, and assessments to

(

determine compliance status and options for remedial/cleanup and compliance measures, including evaluation and use of new cleanup technologies; support of pollution prevention, restoration, and other environmental program initiatives.

PROJECT JUSTIFICATION/DESCRIPTION:
Proposed environmental program activities for Fiscal Year 2000 total $40.1 million. This program represents this year's request on a phased approach in relation to the total Agency requirements for the environmental remediation activities that must be implemented within the next several years, as well as needed requirements for other environmental compliance measures. Based on relative urgency and potential health hazards, the listed activities are the highest priority requirements currently planned for accomplishment in FY 2000. Deferral of these necessary compliance and remedial measures would preclude NASA from complying with environmental requirements and regulatory agreements, and jeopardize critical NASA operations. As studies, assessments, remedial investigations, feasibility studies, and designs progress and as new discoveries or regulatory requirements change, it is expected that priorities may change and revisions of these activities may be necessary.

Remediation activities include one or more phases of a site cleanup program, including but not limited to, the following: 1) site assessments; 2) site investigations; 3) interim cleanup actions; 4) testing and evaluation; and 5) remedial treatment processes and other activities associated with the CERCLA/RCRA cleanup requirements.

The following broad environmental categories summarize the effort to be undertaken with the identified estimated costs:

a.	Remediation Activities and Initiatives (e.g. CERCLA, RCRA)	$34,540,000
b.	Other Environmental Compliance Requirements and Initiatives -- Compliance, Restoration, Prevention, Closure Activities and Initiatives -- (e.g. CAA, CWA, RCRA, ESA, AEA, PPA)	5,560,000

CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
RCRA = Resource Conservation and Recovery Act
CAA = Clean Air Act
CWA = Clean Water Act
ESA = Endangered Species Act
AEA = Atomic Energy Act
PPA = Pollution Prevention Act

COST ESTIMATES:

A. Dryden Flight Research Center (DFRC)	$600,000
1. Remediation of Soil/Groundwater Contamination	600,000
B. Glenn Research Center (GRC)	$2,550,000
1. Remediation of UST Sites. PBS	1,000,000
2. Remediation Activities at Operable Units, PBS	650,000
3. Plum Brook Reactor Decommissioning Activities	900,000
C. Jet Propulsion Laboratory (JPL)	$4,700,000
1. Remediation of Arroyo Seco Groundwater Contamination	4,700,000
D. Johnson Space Center (JSC)	$1,300,000
1. Environmental Assessment/Cleanup for NASA Industrial Plant. Downey	250,000
2. Storm/Sanitary Cross Connections Compliance	400,000
3. Closure of Treatment Systems, B410 & B223	650,000
E. Kennedy Space Center (KSC)	$6,020,000
1. Remediation of Launch Complex 34	1,200,000
2. Remediation of Hydrocarbon Bum Facility	1,000,000
3. Remediation of Central Heating Plant	600,000
4. Remediation of Components Cleaning Facility Laboratory. Phase 2	1,000,000
5. Interim Remediation of Crawler Park Sites, West	400,000
6. Remediation of Contractor Heavy Equipment Area	670,000
7. Remediation of Hypergol Support Building, M7-1061	150,000
8. Restoration of Wetlands and Scrub Habitat, Phase 3	600,000
9. Various Interim Remedial Actions, Various Locations	400,000
F. Marshall Space Flight Center (MSFC)	$6,825,000
1. CERCLA Investigation and Cleanup	5,625,000
2. RCRA Investigation and Cleanup, Santa Susana Field Laboratory (SSFL)	500,000
3. Sewer System Rerouting and Compliance Modifications	700,000
G. Michoud Assembly Facility (MAF)	$1,250,000
1. Remediation Activities. Various Locations	1,250,000

H.	Stennis Space Center (SSC)	$3,600,000
	1. Remediation Activities at Various Sites	3,600,000
I.	Wallops Flight Facility (WFF)	$1,100,000
	1. Remediation of Advanced Data Acquisition System Radar Antenna Site, N168	800,000
	2. Wastewater Treatment Plant De-nitrication Process Upgrade	300,000
J.	White Sands Test Facility (WSTF)	$3,200,000
	1. Groundwater Contamination Assessment and Remediation	3,200,000
K.	Studies, Assessments, and Investigations; Plans; Designs; Sampling, Monitoring and Operation of Remedial Treatment Processes; Related Engineering and Program Support	$8,955,000
	Total Environmental Compliance and Restoration (ECR) Program	$40,100,000

FUTURE ESTIMATED PROGRAM FUNDING REQUIRED:

Requirements will be re-evaluated each year to ensure the necessary activities are accommodated within the budget. Specific outyear funding levels will become better defined as plans and estimates are completed, and planned activities are reviewed and coordinated with federal, state, and local regulators.

INSPECTOR GENERAL

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF INSPECTOR GENERAL

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998 OPLAN 9/29/98	FY 1999 OPLAN 12/22/98	FY 2000 PRES BUDGET
	(Thousands of Dollars)		
Personnel & Related costs	16,574	18,500	19,200
Travel	758	900	1,000
Operation of Installation	820	600	600
Facilities services	(--)	(--)	(--)
Technical services	(225)	300	300
Management and Operations	(595)	300	300
Total	18,152	20,000	20,800
Distribution of Program Amount by Installation			
Headquarters	18,137	20,000	20,800
Gadded Space Flight Center	15	0	0
Total	18,152	20,000	20,800

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

OFFICE OF INSPECTOR GENERAL

The NASA Office of Inspector General (OIG) budget request of $20.8 million for FY 2000 is based primarily on 210 Full-Time Equivalents (FTEs). The personnel and related cost of the 210 FTEs represents approximately 92 percent of the total OIG budget request. (We currently are staffed at a 185 FTE level) The FTE level of 210 allows the OIG to hire for the Computer Crimes Division staff skilled in forensic evidence retrieval and advanced programming. This staff is needed to evaluate the serious international penetrations targeted at NASA's systems. Our request and FTE requirements will allow the OIG to perform its legislated mission as well as respond to Congressional requests for Government Performance Results Act reviews. At the requested level, the OIG will: (1) provide assistance and work cooperatively with Agency management as it carries out NASA's programs and operations; (2) maintain a balanced audit program, including providing technical assistance and oversight of the audit of the Agency's financial statements as required by the Chief Financial Officers (CFO) Act; (3) concentrate investigative resources on procurement fraud and network, computer, and telecommunications crime matters including emphasis on prevention initiatives; (4) work cooperatively with management by conducting inspections, assessments and reviews of issues identified by the OIG, and those of concern to Agency management and Congress; and (5) deploy audit staff to timely provide feedback on NASA's re-engineering and streamlining initiatives. This budget level recognizes the fiscal constraints facing the Agency and the need for the OIG to provide quality products and services that are timely and meet our customers' needs. In light of increasing budget constraints, the Inspector General continues streamlining activities to increase the mission capability of the OIG staff. Initiatives include continued conversion of administrative overhead positions to program assistants and analysts responsible for assisting on direct mission activities of the audit, investigative, and inspection missions; and matrixing existing personnel and management analyst positions to support direct mission activities. In addition, the OIG continues to streamline and simplify communications and reporting channels, and improve computer and telecommunications capacities to further increase staff capabilities.

The OIG's missions include conducting independent audits, investigating, and inspecting/assessing/reviewing NASA's programs and operations while working as cooperatively as feasible with NASA's management and program managers. Audits will be prioritized and selected to evaluate programmatic, operational and financial management concerns, information technology systems and operations, and internal control vulnerabilities. The investigations program, with its computer and network crimes capability, will continue to place greater emphasis on the investigation of computer intrusions and frauds in which the computer was used as an instrument of the crime. The remaining investigation's program will focus on complex procurement and other fraud matters including fraud against the Government by contractor and Government employees, product substitution, and other procurement irregularities. Each investigative matter will be approached on a programmatic, priority basis to identify preventive initiatives. Inspections, assessments, and reviews will be conducted which support: management's interests and concerns in achieving NASA's programmatic objectives more efficiently and effectively; issues of Congressional concern; matters of high Agency vulnerability; and administrative inquiries related to unethical and improper conduct, waste and mismanagement.

OBJECTIVES AND STATUS

This request represents the OIG resources (FTEs) needed at NASA Headquarters and field offices to fulfill the OIG mission. Recognizing that every identified audit, investigations, inspections, assessments, and other workload reviews significantly exceed the available resources, continuous adjustments of priorities will be necessary to ensure: a balanced coverage of NASA's programs and operations is maintained; all critical and sensitive matters are promptly evaluated and investigated; and all OIG customers receive timely, accurate, and complete responses.

The OIG uses a formal, comprehensive process to identify, review, prioritize, and select the audits, inspections, evaluations, and reviews that are to be performed. The OIG assignments are derived from: (1) monitoring NASA's evolving initiatives in downsizing, re-engineering, commercialization, and privatization to determine opportunities for efficiencies and vulnerabilities; (2) selecting audits and reviews using a structured approach encompassing NASA's programs and operations and an external universe comprised of NASA's prime contractors, their subcontractors, and grantees; and (3) addressing issues required by laws and internal regulations. The audits and reviews identified from these sources are prioritized and compared to available resources and published in the annual OIG work plan. The OIG will continue its NASA-wide program-oriented reviews to obtain greater visibility and awareness of issues related to NASA's major programs and initiatives.

Agency vulnerabilities are determined by taking into consideration the following: (1) whether program and project objectives are accomplished in the most cost effective manner and comply with safety and mission quality initiatives; (2) whether management's actions are sufficient to correct internal control weaknesses reported under the Federal Manager's Financial Integrity Act (FMFIA); (3) whether NASA's annual expenditure on information technology is providing expected programmatic and financial information needed to make sound decisions (NASA is one of the top ranked civilian agencies in information technology spending); (4) whether improvements are implemented in financial management systems, practices, controls, and information; (5) whether the audit follow-up system is effective in enabling management to maintain the status of corrective actions; and (6) whether Agency-wide corrective actions addressing environmental concerns are adequate. Each of the identified vulnerabilities are evaluated, prioritized, and included in our plans for further action.

Further, Agency program and project changes, growth, delays, and termination increase the need for OIG oversight of contractor/subcontractor/grantee cost, schedule, and performance effectiveness. Leading up to, during, and beyond FY 2000, the Agency will potentially be faced with an array of problems resulting from computer systems not being able to successfully transition to the "00" calendar year. It has been estimated that the Year 2000 problems will extend beyond the first decade of the 21st century. Moreover, the Agency is developing a number of technology programs that will be reaching critical milestones in FY 2000 and beyond that have not received audit coverage. The OIG needs to increase its investment in information technology capabilities through additional staffing that can be initially dedicated to FY 2000 computer problems. The NASA's continued reliance on contractors and grantees (about 90 percent of the Agency's total obligations are for procurement) will require increasing direct OIG involvement and oversight of Defense Contract Audit Agency (DCAA) and Health and Human Services (HHS) OIG audits of NASA contractors and grantees to ensure effective contract and grant execution and administration. During FY 1998, NASA was billed approximately $41 million for contract audit services.

During FY 2000, the OIG will continue to focus attention and provide support to program managers on issues relating to: Earth Science, Communications, Human Exploration and Development of Space, Space Technology, Information Technology, Aeronautics, and Space Transportation. The functional areas we will evaluate include Procurement and Contract Administration, Technology Transfer, Financial Management, Information Resources Management, Information Systems and Communications Security, and Facilities and Equipment. The OIG's Information Technology Program and Information Assurance audit groups will continue to focus on the security and integrity of NASA's major information systems and operations. Financial management's significance increased with the passage of the CFO Act. Pursuant to the Inspector General Act and Title 31, we have selected independent auditors to render an opinion on the Agency's annual financial statements, its internal control structure, and its compliance with laws and regulations. Our financial audits will concentrate on accounting controls, information systems, and required performance measurements.

The OIG investigative workload continues to exceed the availability of investigative resources. The FY 2000 investigative staffing level will require OIG management to effectively manage the complex workload of investigative criminal and civil fraud matters. The establishment of the Computer Crimes Division allows the OIG to investigate unauthorized intrusions into and compromises of NASA and contractor computer systems, as well as assessing vulnerability to information terrorism. The increase in the computer crimes investigative caseload will rise significantly by FY 2000. Because of our growing expertise, our focus is now on intrusions of NASA's networks and systems, and economic espionage as well as other serious intrusions which cause losses of communications services involving hundreds of thousands of dollars per intrusion, using NASA funded networks to further other criminal enterprises including the compromise of advanced technologies and industrial espionage. The number of complex procurement fraud cases also remains high. Such cases take longer to resolve and are resource intensive, thereby limiting our flexibility to expand the program. We are currently proactively focusing on program fraud areas identified by our audits as highly vulnerable to fraud. We are working with management to help us address all substantive allegations received, to refer more routine administrative matters to them for their resolution, and request that they keep the OIG advised of the action taken. We are also referring more serious administrative matters to the OIG Inspections and Assessments (I&A) staff for review. By referring matters to Agency managers and the I&A staff to resolve, we can reserve our investigative resources to address the more serious fraud allegations made to the OIG.

In summary, the OIG will collaborate with Agency management to address issues of joint concern to: improve scope, timeliness, and thoroughness of its oversight of NASA programs and operations; identify preventive measures; and enhance our capabilities to assist NASA management to efficiently and effectively achieve program and project goals and objectives.

SCHEDULE & OUTPUTS

WORKLOAD	FY 1998	FY 1999	FY 2000
Office Staff Ceiling			
Full-Time Equivalents	185	210	210
Investigations			
Cases pending beginning of year	257	288	316
Opened during year	185	230	252
Closed during year	220	215	235
Cases pending end of year	288	316	346
Audits			
Audits pending beginning of year	52	34	48
Opened during year	26*	69	65
Closed during year	44	55	60
Audits pending end of year	34	48	53
Inspections & Assessments (IA) and Partnerships & Alliances (PA)			
IA Administrative Investigations pending beginning of year	19	87	105
Opened during year	153	168	160
Closed during year	85	150	155
IA Administrative Investigations pending end of year	87	105	95
IA and PA Reviews pending beginning of year	13	11	12
Opened during year	21	29	29
Closed during year	23	28	28
IA and PA Reviews pending end of year	11	12	13

*Emphasis on programmatic audits

BASIS OF FY 2000 FUNDING REQUIREMENT

PERSONNEL AND RELATED COSTS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Compensation and Benefits	**15,979**	**18,155**	**18,835**
Compensation	13,073	15,010	15,483
(Full-time permanent)	(12,810)	(14,730)	(15,283)
(Other than full-time permanent)	(9)	(--)	(--)
(Overtime & other compensation)	(254)	(280)	(200)
Benefits	2,906	3,145	3,352
Supporting Costs	**595**	**345**	**365**
Transfer of personnel	478	110	180
Personnel training	102	220	170
OPM Services	15	15	15
Total	**16,574**	**18,500**	**19,200**

	FY 1998	FY 1999	FY 2000
		(Full-Time Equivalents)	
Full-time permanent	184	210	210
Other controlled FTEs	1	--	--
Total	185	210	210

These estimates provide the resources required for full staffing of NASA OIG's Information Technology Audit and Computer Crimes Divisions.

TRAVEL

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Travel	758	900	1,000

Travel funding is required to carry out audit, investigation, inspection and assessment, partnerships and alliances, and management duties. Our budget allows for increases in per diem, airline costs, and workloads. We anticipate increased travel by our information technology audit and computer crimes teams. Also, in order to respond to NASA's changing priorities (and implementation of its centers of excellence and commercialization efforts), increased travel funds will be required to deploy staff located at field offices remote from the site where audit and investigation activities occur.

OPERATION OF INSTALLATION

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Technical Services	225	300	300
Management and Operations	595	300	300
Total	820	600	600

Operation of Installation provides a broad range of services and equipment in support of the Inspector General's activities.

The Technical Services estimate provides for all equipment, including purchase, maintenance, programming and operations of unique automated data processing (ADP) equipment. NASA provides common services items such as office space, communications, supplies, and printing and reproduction at no charge to the Office of Inspector General. The funding for Technical Services will cover the cost of providing unique ADP upgrades, and replacement of unique equipment that has become outdated or unserviceable. As funding permits, in FY 2000 we will continue to improve our PC-based wide-area network and management information system.

The Management and Operations category includes miscellaneous expenses within the Office of Inspector General, i.e., GSA cars, the Inspector General's confidential fund, miscellaneous contracts, and supplies not provided by NASA.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROPOSED APPROPRIATION LANGUAGE

OFFICE OF INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the Inspector General Act of 1978, as amended, [$20,000,000] *$20,800,000.* (*Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1999.*)

TABLE OF CONTENTS

SPECIAL ISSUES

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 2000 BUDGET ESTIMATES
FULL-COST MANAGEMENT

During 1995, the National Aeronautics and Space Administration (NASA) began a multi-year initiative to introduce full-cost practices into NASA. Full-cost practices involve new management, budgeting, and accounting changes. The changes are designed to provide new detailed, complete cost information and thereby support improved (more cost effective) mission performance and related administrative improvements. Full-cost practices (also for brevity collectively referred to as full-cost management) integrate new cost accounting information on all aspects of NASA's activities. Managers to ensure that all activities cost-effectively support NASA missions will use this information. Full-cost budget information will highlight the full cost (including support costs) of each NASA project and thereby support more complete, "full" disclosure of NASA's activities, clearer linkage between resource inputs and outputs/outcomes, and greater accountability regarding NASA's use of taxpayer resources.

NASA's full cost practices are designed to provide useful, detailed cost information for internal management and appropriate cost information for external oversight. Such information is expected to result in improved decisions and more cost effective mission performance. NASA's practices also comply with related Federal legislation, such as the 1990 Chief Financial Officers (CFO) Act, the 1993 Government Performance and Results Act (GPRA) and the 1996 Federal Financial Management Improvement Act.

As NASA formulates its FY 2001 budget request, the decision process will be conducted using information on the full costs of its programs. Concurrently, NASA will be working with the Administration and the Congress to develop the new appropriation structure, the necessary transition mechanisms from the present account structure and the changes to agreements on Operating Plan reprogramming procedures. Particular attention will be paid to the need for flexibility on allocation of civil service and supporting costs among programs and projects in the Research and Development environment. Timely conclusion of these precursor discussions is critical to the future implementation of a full cost appropriation budget presentation for FY 2001, and the execution of the enacted appropriation. NASA will also be closely monitoring the progress being made on the installation of a new, NASA-wide standard, integrated financial management system. Current plans call for the new systems and procedures to be installed across NASA in a phased manner during 1999 and 2000. The capabilities of the new system for budget execution and accounting are essential to meeting the internal control standards required to execute the FY 2001 appropriation in a full-cost environment.

NASA has tested full-cost concepts across the agency and determined the feasibility of implementation and anticipated benefits, most recently conducting a Full Cost Simulation across the agency in conjunction with the initial FY 2000 budget request. This simulation identified the need for additional process improvements and clarifications in the draft guidance documents. Provided below is a summary of the status, purpose and background of NASA's full-cost initiative. Also highlighted are key legislative authorities that will support the timely, effective implementation of full cost practices in NASA. Supplemental information is available through the NASA CFO Internet site at http://ifmp.nasa.gov/codeb/initiatives/standard.htm

Purpose

The purpose of the full-cost initiative is to develop and implement full-cost accounting, budgeting, and management practices in NASA. The purpose of implementing such full-cost management is to support cost-effective mission performance through timely, reliable financial information and practices.

Simply stated, full-cost management can be expected to help to ensure optimum mission performance with the minimum essential resources. In that regard, full-cost practices are expected to:

- Support more cost effective mission performance
- Motivate managers to operate efficiently
- Support economic decisions for appropriate resource allocations
- Help justify NASA's budget on a program/project basis
- Support analysis and decision-making regarding full project costs
- Support analysis and decision-making regarding NASA services provided to others (reimbursable activities)
- Support bench-marking of NASA service activities with other similar services
- Strengthen accountability regarding NASA's effective and efficient use of tax dollars to achieve NASA missions.

NASA is pursuing full-cost management at this time because NASA requires related cost information to more effectively manage within the current and anticipated future environment. This environment includes constrained budgets and increased expectations regarding oversight and accountability.

Background

NASA's full-cost management initiative began in 1995 in response to guidance from several NASA and Federal authorities. While the initiative was undertaken in direct response to a specific management initiative of the NASA Administrator, the initiative also responded to guidance indicated in NASA's 1995 Zero Base Review and mandates in several key Federal financial and performance laws and related standards.

In early 1995, the NASA Administrator requested key cost information for NASA and for each NASA Center. In pursuing the Administrator's request, the NASA Chief Financial Officer confirmed that NASA's nonstandard, decentralized accounting systems did not regularly capture all required cost information in a timely, standard, useful manner. Shortly thereafter, in April 1995, NASA initiated its full-cost effort.

During 1995, NASA also completed a Zero Base Review that involved a comprehensive analysis related to streamlining NASA activities. This review also highlighted several weaknesses involving the inconsistent recognition of the total costs of certain NASA activities and the related analytical complications of inconsistent cost information. The Zero Base Review team indicated that NASA should improve cost information and pursue full-cost management.

During 1995, Federal accounting standards-setting organizations also completed key initiatives related to cost accounting. These organizations approved a new managerial cost accounting standard, including a specific standard on full-cost accounting. This standard (and other Federal accounting standards) evolved from recent Federal financial and performance legislation.

During the past few years, financial and performance legislation highlighted key Federal cost accounting and reporting requirements. This legislation included the CFO Act of 1990 and the Government Performance and Results Act of 1993. In addition, more recently the Federal Financial Management Improvement Act of 1996 highlighted and specified other key full-cost accounting requirements. The 1996 Act stated the following.

> "The purposes of this Act are to...require Federal financial systems to support full disclosure of Federal financial data, including the full costs of Federal programs and activities, to the citizens, the Congress, and President, and agency management, so that programs and activities can be considered based on their full costs and merits..."

> "Each agency shall implement and maintain management systems that comply substantially with Federal financial management systems requirements, applicable Federal accounting standards, and the United States Government's Standard General Ledger at the transaction level."

NASA's full-cost initiative evolved from these internal NASA initiatives, as well as, several related Government-wide initiatives.

During 1995, NASA developed key full-cost concepts and specified related cost information requirements as part of an ongoing Integrated Financial Management system initiative. NASA's full-cost concepts were approved by NASA management in early 1996.

NASA's full-cost concept integrates several fundamental improvements. The planned improvements include accounting for all NASA costs as direct costs, service costs, or general and administrative (G&A) costs, budgeting for all appropriate program/project/initiative ("project") costs, and managing such "projects" from a full-cost perspective. Direct costs are costs that can be obviously and/or physically linked to a particular project. Service costs are costs that cannot be initially, readily and/or immediately linked to a cost objective, but subsequently can be traced either to a project or to G&A activities (optimally based on service consumption). G&A costs are support costs that either cannot be to a specific project or where the expense of doing so would be uneconomical. Such costs are typically allocated to cost objectives (or projects) by using allocation methods, which meet the tests of reasonableness and consistency.

During 1996, NASA tested full-cost concepts at four NASA prototype test locations (three Centers and Headquarters). The prototype test indicated that NASA could benefit significantly from the introduction of full-cost practices throughout the agency.

During 1997, NASA completed an agency-wide test of full-cost practices that confirmed its earlier observations that NASA could benefit significantly from the implementation on full-cost practices. The 1997 test also confirmed that NASA needed a new integrated financial system to cost effectively and efficiently support full cost budgeting and accounting. Cost finding techniques that were used to develop full cost accounting estimates after-the-fact proved to be extremely resource-intensive and could not produce needed data in a timely fashion. Furthermore, the timely, efficient formulation of the budget in a full cost format also proved to be extremely resource-intensive and basically unworkable as an ongoing approach.

Status

During 1998, NASA continued testing and refining full-cost practices. A Full Cost Simulation was conducted across the agency utilizing an early version of the FY 2000 budget proposal. The major focus of this simulation was to determine how best to manage in the full cost environment, particularly in regard to service pools and G&A expense pools. Field Center and Headquarters results and issues were presented to a panel of Deputy Center Directors and Deputy Associate Administrators from throughout the agency, who made management recommendations which are to be integrated into the agency's Full Cost Implementation Guide.

This 1998 test also served as the first utilization of an early version of the Integrated Financial Management System (IFMS) budget formulation module. This so-called "early budget" version of the integrated system was contracted for earlier than the full system to test the capabilities of the system. The successful event demonstrated several key anticipated system/process efficiencies. Testing continues on the integrated IFMS, which remains on schedule for a phased, agencywide implementation in FY 1999 and FY 2000. In FY 1999, NASA plans to utilize the budget formulation module to develop budgetary requirements for the FY 2001 submission.

NASA Proposal for Optimization of Full-Cost Management

The strength and benefits of NASA's full cost practices are optimized by the integration and synergy of changes in each area (management, budgeting, and accounting). Full-cost accounting by itself, over time, would likely lead to gradual budget and management improvements. However, concurrent changes to full cost practices in the accounting, budgeting, and management areas can be expected to ensure that NASA optimizes improvements in each area, as soon as possible. To this end, NASA has decided to pursue key appropriation/budget structure changes as part of the full cost initiative. Furthermore, certain legislative provisions are being pursued to ensure that NASA achieves all of the key benefits of its full-cost practices, while NASA retains its long-standing ability to appropriately and efficiently assign/reassign its staff to achieve mission requirements.

NASA plans to work with OMB and Congress in 1999 in order to pursue legislative proposals to optimize the implementation of full cost practices. It is expected that discussions will focus on the agency's appropriation/operating plan/budget structure and the levels of Congressional control; alternative solutions for utilization of unobligated and unexpired balances available under the current appropriation structure; the establishment of an agency "working capital" fund, and other operational matters.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 ESTIMATES

COMPARISON OF CURRENT BUDGET STRUCTURE VS. MODIFIED BUDGET STRUCTURE

	BUDGET PLAN		
CURRENT BUDGET STRUCTURE	FY 1998	FY 1999	FY 2000
HUMAN SPACE FLIGHT	**5,559.5**	**5,480.0**	
SPACE STATION	2,331.3	2,304.7	
US/RUSSIAN COOPERATION	110.0	--	
SPACE SHUTTLE	2,912.8	2,998.3	
PAYLOAD UTILIZATION AND OPERATIONS	205.4	177.0	
MODIFIED BUDGET STRUCTURE	FY 1998	FY 1999	FY 2000
INTERNATIONAL SPACE STATION			**2,482.7**
SPACE STATION			2,482.7
LAUNCH VEHICLES AND PAYLOAD OPERATIONS APPROPRIATION			**3,155.3**
SPACE SHUTTLE			2,986.2
PAYLOAD UTILIZATION AND OPERATIONS			169.1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000 BUDGET ESTIMATES

MULTI-YEAR APPROPRIATIONS
(IN MILLIONS OF REAL YEAR DOLLARS)

NASA is seeking multi-year appropriations for the following selected projects:

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004
INTERNATIONAL SPACE STATION	2482.7	2328.0	2091.0	1721.1	1573.0

National Aeronautics and Space Administration

Major NASA Development Programs
Program Cost Estimates

This special section of the FY 2000 budget justifications provides information about major NASA programs that are either in the design and development phase or have not completed their initial operational phase. In several instances, information about programs which are not "major" but are of special interest has been included. The budgetary estimates are expressed in millions of dollars of *budget authority*. * Estimates of the FY 1998 and prior fiscal year budget authority are the "actual" amounts. The FY 1999 amounts are consistent with the FY 1999 initial operating plan. The amounts for FY 2000 and future fiscal years are expressed in "real year" economics, that is, they include an adjusting factor for the future inflation expected to be experienced. If the term "constant dollars" is used in the budget justifications, that phraseology indicates that the numbers do not include inflationary adjustments beyond the fiscal year referenced (e.g., "constant FY 1994 dollars").

The estimates provided below are intended to be comprehensive, including all related mission-unique costs, but there are limitations. The direct and indirect costs incurred by foreign governments or other federal agencies in support of these missions have not been included. (The reader is referred to the NASA Program Status Reports, a biannual document published by NASA, for the most accurate information available to NASA on the amounts incurred or to be incurred.) The estimates of civil service costs have been included, but these estimates should be considered preliminary, and they will continue to be refined as the agency moves toward full cost accounting over the next two years.

* *Budget authority* is a term used to represent the amounts appropriated by the Congress in a given fiscal year; *budget authority* provides government agencies with the authority to obligate funds. The ensuing obligations, cost incurrence, and expenditures (outlays) can differ in timing from the fiscal year in which Congress provides the *budget authority* in an appropriations act.

High Speed Research Program

While NASA was on track to meet the original High Speed Research Program goals, technology advancements in subsonic commercial transports have resulted in a much quieter fleet. As a result, the original noise requirements are now insufficient for the HSCT to blend into the surrounding aircraft noise levels. Although dramatic advances were made against the original program goals, the recent application of more stringent noise constraints to ensure an environmentally compatible high-speed civil transport (HSCT) led to designs that require significant advances in propulsion technology. Our industry partners indicated that product development would be significantly delayed leading to the decision to terminate the focused HSR program at the end of FY 1999.

NASA's HSR program has made significant contributions to aeronautics state of the art. It has provided a public-sector catalyst in addressing this important opportunity with U. S. industry through a two-phase approach. The first phase, successfully completed in 1994, defined HSCT environmental compatibility requirements in the critical areas of atmospheric effects, community noise and sonic boom and Several milestones—including completion of a preliminary noise assessment; selection of engine cycle, inlet, and nozzle concept; selection of candidate flight deck concepts; identification of preliminary wing and fuselage structural concepts; and, ultimately, definition of a technology concept—contributed to a technology foundation that provided confidence that the necessary technology could be developed. The second phase was a cooperative program with U. S. industry, directed at developing and validating designs, design methodologies and manufacturing process technology for subsequent application by industry in future HSCT aircraft programs to ensure environmental compatibility and economic viability. As HSR Phase II is concluded, it will have exceeded the original HSR Phase II program goals planned through FY 1999 for environmental compatibility and economic viability. As an example of the highly successful nature of this program, the technology concept airplane (TCA) baseline defined in December 1998 is several decibels quieter than the original HSR noise goals. Accomplishments contributing to TCA definition include successful completion of subscale combustor tests and large-scale nozzle tests; selection of turbine airfoil alloy and turbomachinery disk material; selection of a combustor configuration; completion of wing and fuselage subcomponent tests; and completion and evaluation of supersonic laminar flow control tests.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	1134.5	245.0	180.7							1560.2
(ESTIMATED CIVIL SERVICE FTEs)	(3,025)	(506)	(402)							
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	197.1	41.5	34.0							

Advanced Subsonic Technology

The AST program was planned and designed to develop, in partnership with the FAA, the U.S. aeronautics industry and universities, high-payoff, high-risk technologies to enable a safe, highly productive global air transportation system that includes a new generation of environmentally compatible, operationally efficient U.S. subsonic aircraft. The critical needs were selected on the basis of industry/FAA technology requirements to provide a focused and balanced foundation for U.S. leadership in aircraft manufacturing, aviation system safety, and protection of the environment.

The AST Program consisted of 5 elements: Safety, Environment, Economics, Reduced Seat Cost, and Capacity. Due to other pressing Agency needs in general and aeronautics needs in particular, the AST program will be concluded in FY 1999. However, the Capacity element is now identified as a separate focused program, "Aviation System Capacity" and is described separately. Aggressive technology transition plans for the conclusion of the remainder of the AST elements were pursued in order to mitigate the significant risk to successful technology transfer to industry as a result of early termination. Budgetary constraints notwithstanding, the AST program has been successful and progress was made toward meeting the current program goals.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	443.2	144.4	89.6							677.2
(ESTIMATED CIVIL SERVICE FTEs)	(1,883)	(352)	(324)	(7)	(7)	(7)	(7)	(7)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	126.3	28.8	27.4	0.6	0.6	0.7	0.7	0.7		

Aviation System Capacity

The goal of the Aviation System Capacity (ASC) program, formerly an element within the Advanced Subsonic Technology Program, is to enable safe increases in the capacity of major US and International Airports through both modernization and improvements in the Air Traffic Management System and the introduction of new vehicle classes which can potentially reduce congestion, specifically: to increase National Airspace System (NAS) throughput while assuring no degradation to safety or the environment; to increase the flexibility and efficiency of operations within the NAS for all users of aircraft, airports and airspace; and to reduce system inefficiencies.

The ASC program is composed of the Terminal Area Productivity (TAP), Advanced Air Transportation Technology (AATT), and the Civil Tiltrotor (CTR) projects. The TAP project develops technology and procedures to support the aviation systems infrastructure by reducing system delays and enabling new modes of airport operation to support "Free Flight". The AATT project develops decision making technologies and procedures to provide all airspace users with more flexibility and efficiency, as well as enable new modes of operation that support the FAA commitment to "Free Flight". The CTR project develops technologies and procedures to overcome inhibitors to a civil tiltrotor operating within an improving and modernized air traffic system. The ASC program works closely with manufacturers, the airlines and the FAA, the technology customers, who are responsible for applying the candidate technologies as operational systems.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	132.7	56.7	53.9	60.0	59.2	77.6	71.6	53.1		564.8
(ESTIMATED CIVIL SERVICE FTEs)		(192)	(203)	(207)	(203)	(203)	(197)	(197)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		15.7	17.2	18.5	18.7	19.5	19.9	20.8		

(

X-33 Advanced Technology Demonstrator

The X-33 program will demonstrate, on the ground and on a flight demonstration vehicle, technologies and operations concepts that could reduce space transportation costs to one-tenth of their current level. The X-33 program includes two major decision points. The first decision, whether to proceed with the demonstration phase (Phase II), was made in July 1996 based on specific programmatic, business planning and technical criteria which had previously been agreed upon by NASA, the Office of Management and Budget and the Office of Science and Technology Policy. With Administration approval, Lockheed Martin Skunkworks, Palmdale, CA was chosen as the X-33 industry partner. X-33 flight tests are expected to begin in July, 2000. This date represents a slip of one year since the last budget was presented to Congress. The delay is due to technical and schedule problems. The second decision will be made at the end of the decade. X-33 ground and flight demonstrations, RLV business planning, the Future Space Launch Studies and other X-vehicles will provide the basis for an end-of-the-decade decision called for in the 1994 National Space Transportation Policy on an appropriate strategy for significantly reducing NASA's launch costs. At that time Government and industry may decide to pursue the full-scale development of an operational RLV.

NASA is utilizing an innovative management strategy for the X-33 program, based on industry-led cooperative agreements. As a result of industry's leadership of the program, Government participants are acting as partners and subcontractors, performing only those tasks for which they offer the most effective means to accomplish the program's goals. The Government participants report costs and manpower to the industry team leader as would any other subcontractor. Every NASA center except the Goddard Space Flight Center has a negotiated role on the X-33 program. The Industry-led cooperative arrangement allows a much leaner management structure, lower program overhead costs and increased management efficiency

The X-33 program also funds refurbishment of rocket engine test stands at Stennis in FY 1997 ($2.3 million) and FY 1998 ($3.7 million) to enable testing of X-33 development and flight engines, as well as other future advanced space transportation engines. Civil Service estimates below are for the X-33 cooperative agreement only.

A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
COOPERATIVE AND TASK AGREEMENTS	262.1	298.6	239.1	111.6						911.4
OTHER X-33 ACTIVITIES	249.6	19.7	38.2							307.5
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	511.7	318.3	277.3	111.6						1218.9
(ESTIMATED CIVIL SERVICE FTEs)	(335)	(404)	(329)	(183)	(70)	(13)	(13)	(13)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	26.1	33.1	27.8	16.4	6.5	1.3	1.3	1.4		

Alternate Turbopump Development

Funding to begin development of an alternate design for the two turbopumps driving the Space Shuttle's Main Engine was initiated in FY 1987. The development of a new high-pressure oxygen turbopump and hydrogen fuel turbopump was undertaken to improve the safety, reliability, producibility, and maintainability of the current turbopumps. After an initial period of design and development, problems experienced in early development testing and accompanying increased costs resulted in suspension of the fuel turbopump's development, while development activities concentrated on the oxygen turbopump. Although further development problems were encountered with the oxygen turbopump, their successful resolution led to Congress agreeing in Spring 1994 to resumption of the fuel turbopump's development. The first flight of the oxygen turbopump occurred in 1995, and the initial flight of the fuel pump is currently planned for late 1999, rescheduled from late 1997 due to development problems. The budgetary estimate of $956.3 million includes not only the funding required for the design, development, and extensive testing of these two types of turbopumps, but also the funding needed to produce the flight turbopumps for installation into the main engines for the four-orbiter fleet.

The budgetary estimates provided below are the amounts included in the Human Space Flight appropriation for this program. They do not include the amounts for the use of government facilities and general and administrative support used to carry out the development. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Shuttle program.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	668.5	28.6	16.9	8.5					28.5	751.0
IMPLEMENTATION	116.7	27.9	40.0	20.7						205.3
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	785.2	56.5	56.9	29.2					28.5	956.3
(ESTIMATED CIVIL SERVICE FTEs)	(509)	(30)	(20)	(10)						
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	30.0	2.5	1.7	0.9						

Super Lightweight Tank

The objective of the Super LightWeight Tank (SLWT) is to provide the Space Shuttle with 7,500 pounds of additional performance of payload capability. The weight reduction objective was achieved by selectively substituting high-strength, low-density, aluminum-lithium alloys, redesigning certain structural components, and reducing thermal protection thickness. The new SLWT physically and functionally replaced the existing External Tank (ET) with not launch processing impacts and without detriment to the other Shuttle system elements. NASA was given congressional approval to proceed in January 1994. The External Tank Project Office at the Marshall Space Flight Center in Alabama manages the SLWT, and Lockheed Martin is the ET prime contractor. The first flight of the SLWT (STS-91) was on June 2, 1998. In addition to the design and development costs, the figures shown below as "recurring cost" provide the estimate of the funding required for the external tank program's production of the new tanks. The estimates include the additional material cost which will be incurred in the production of subsequent tanks. The aluminum-lithium material is a specialty metal produced to rigorous specifications and accordingly costs more than the aluminum used at present. The development cost estimate is significantly reduced from the FY 1998 estimate, as contract performance exceeded expectations and project reserves were not required.

The budgetary estimates provided below are the amounts included in the Human Space Flight appropriation for this program. They do not include the amounts for the use of government facilities and general and administrative support used to carry out the development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Shuttle program.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT COST	126.7	0.7								127.4
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	126.7	0.7								127.4
(ESTIMATED CIVIL SERVICE FTEs)	(202)	(29)								
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	14.7	2.4								

Checkout and Launch Control System (CLCS)

A new Checkout and Launch Control System (CLCS) was approved for development at KSC in FY 1997. The CLCS will upgrade the Shuttle launch control room systems with state-of-the-art commercial equipment and software in a phased manner to allow the existing flight schedule to be maintained. The CLCS will reduce operations and maintenance costs associated with the launch control room by as much as 50%, and will provide the building blocks to support future vehicle control system requirements. The Thor and Atlas phases were completed in FY 1998. During these phases, the initial applications for the Orbiter Processing Facility were developed, the math models were validated, Shuttle Avionics Integration Lab interfaces were established, and hardware testing was done. The Titan and Scout phases of CLCS are planned for FY 1999 during which Orbiter automated power-up will be developed, peripheral locations will be upgraded, and selected vertical testing will be done. In FY 2000, the Delta and Saturn phases will be accomplished which includes completion of all launch application development, completion of software certification and validation, and a complete integrated flow demonstration. Since the FY 1999 Budget, software independent validation and verification (IV&V) performed by Ames Research Center was also added to this project. By the end of FY 2000, Operations Control Room-1 will be fully operation, followed by certification in FY 2001. The first Shuttle launch using the CLCS is scheduled for FY 2001 with full implementation to be completed one year later.

The budgetary estimates provided below are the amounts included in the Human Space Flight appropriation for this program. They do not include the amounts for the use of government facilities and general and administrative support used to carry out the development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Space Shuttle program.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT COSTS	22.6	41.0	48.0	48.3	36.1	11.4				207.4
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	22.6	41.0	48.0	48.3	36.1	11.4				207.4
(ESTIMATED CIVIL SERVICE FTEs)	(50)	(105)	(135)	(131)	(77)					
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	3.7	8.6	11.4	11.7	7.1					

TDRS Replenishment Spacecraft Program

The Tracking and Data Relay Satellite (TDRS) Replenishment Spacecraft program ensures sufficient spacecraft will be available to continue Space Network operations into the next century. The program provides three additional TDRS satellites and ground terminal modifications through a fixed price, commercial practices contract with Hughes Space and Communications Company. This innovative approach has deleted or greatly reduced Government specifications and documentation requirements, allowing the contractor to substitute commercial practices; this has resulted in efficiencies in both cost and development lead time.

These satellites will incorporate Ka-band frequencies, where space research has a primary allocation, into the high data rate services provided via the high gain, single access antennas. The single access services at S-band and Ku-band will be retained, remaining backward compatible with the existing, first generation TDRS satellites. These satellites will also provide an enhanced multiple access service with data rates up to three megabits per second. The first spacecraft remains on schedule for launch in the third quarter of 1999.

The estimates do not include costs for use of government facilities and general and administrative support used to carry out the program. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification for the program within the Space Communications section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
SPACECRAFT DEVELOPMENT AND GROUND TERMINAL MODIFICATIONS	356.9	56.0	66.7	17.7	14.5	57.7	6.5			576.0
LAUNCH SERVICES	24.7	52.0	34.8	13.5	40.5	67.8	37.0			270.3
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	381.6	108.0	101.5	31.2	55.0	125.5	43.5			846.3
(ESTIMATED CIVIL SERVICE FTEs)	(119)	(41)	(39)	(43)	(42)	(42)	(42)	(7)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	8.0	3.4	3.3	3.8	3.9	4.0	4.2	0.7		

Advanced X-Ray Astrophysics Facility

The design and development of the Advanced X-Ray Astrophysics Facility (AXAF) was approved by Congress in the FY 1989 budget. The AXAF is the third of the four "Great Observatories" intended to observe the universe in four electromagnetic spectrum regions: visible, infrared, gamma ray, and x-ray. The initial phase of the AXAF's development was limited to a feasibility demonstration of the new mirror technology required to achieve the AXAF's objectives. A specially designed x-ray calibration facility was constructed to assure the mirrors meet their design specifications. The second phase was approved by Congress after the demonstration mirrors were successfully tested. In 1992, NASA management directed the restructuring of the AXAF program to reduce projected future funding requirements. A two-spacecraft approach was selected, a large imaging spacecraft (**AXAF-I**maging) and a smaller spectroscopy spacecraft (**AXAF-S**pectroscopy). In 1993, Congress directed the elimination of the AXAF-S. The current launch date for the AXAF-I is April 1999 aboard the Space Shuttle, with an Inertial Upper Stage (IUS) providing delivery into a highly elliptical orbit around the Earth. This date represents a slip of approximately 4 months since the FY 1999 budget was sent to Congress, as previously reported in a letter to the Committees on November 13, 1998. The slip resulted from the need to perform additional software development and testing, as well as from NASA's desire to gain assurance that the spacecraft systems and operating procedures have been tested sufficiently to enable a successful mission. Moreover, in mid-January 1999, following the successful completion of AXAF testing, TRW discovered a problem with circuit boards on some of their spacecraft, including AXAF. The project is currently investigating the extent of the problem on AXAF; however, it appears that the minimum launch delay will be five weeks, or until May 1999. The potential exists for a much longer delay, but at this time the scope of the problems, and the length of the delay, are yet to be determined. NASA will not launch AXAF until we are certain that we have a world-class observatory that has been thoroughly tested and meets all requirements. NASA will inform the Administration and Congress of the new AXAF launch date as soon as possible.

The budgetary estimates provided below encompass: the early development of the mirror technology; the design and development phase; establishment of a mission-unique science center and preflight ground system development, followed by a five-year period (1999-2003) of mission operations and science data analysis; the purchase of the IUS and integration activities; the average cost (including recurring costs for improvements and upgrades) of an FY 1998 Space Shuttle flight; mission-unique tracking and data support costs; and, the construction of the X-Ray Calibration Facility. The estimates below also include a pro forma distribution of the average costs of a Space Shuttle. They do not include the amounts being contributed by international participants, or for the use of non-program-unique government facilities and general and administrative support used to carry out the research and development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
ADVANCED TECH DEVELOPMENT	54.2									54.2
DEVELOPMENT	1,365.8	103.9	39.0							1,508.7
MISSION OPS & DATA ANALYSIS	128.4	41.5	55.5	60.5	59.7	61.6	59.7	49.2	225.2	741.3
UPPER STAGE	65.6	8.3	2.0							75.9
STS LAUNCH SUPPORT	191.5	76.5	114.9							382.9
TRACKING & DATA SUPPORT	1.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	3.0
CONSTRUCTION OF FACILITIES	17.7									17.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	1,824.4	230.5	211.6	60.7	59.9	61.8	59.9	49.4	225.5	2,783.7
(ESTIMATED CIVIL SERVICE FTEs)	(1,528)	(123)	(125)							
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	96.9	10.1	10.6							

Space Infrared Telescope Facility (SIRTF)

The purpose of the Space Infrared Telescope Facility (SIRTF) mission is to explore the nature of the cosmos through the unique windows available in the infrared portion of the electromagnetic spectrum. SIRTF is the fourth of NASA's Great Observatories, which include the Hubble Space Telescope, the Compton Gamma Ray Observatory, and the Advanced X-Ray Astrophysics Facility. The funding plan provided below reflects a dramatic restructuring of the SIRTF design concept carried for many years. Rather than simply "descoping" the "Great Observatory" concept to fit within a $400 million (FY94 $) cost ceiling imposed by NASA, scientists and engineers have instead redesigned SIRTF from the bottom-up. The goal was to substantially reduce costs associated with every element of SIRTF -- the telescope, instruments, spacecraft, ground system, mission operations, and project management. The Jet Propulsion Laboratory (JPL) was assigned responsibility for managing the SIRTF project. SIRTF is planned for launch on a Delta launch vehicle during FY 2002.

The budgetary estimates below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts for the definition phase studies carried out prior to FY 96. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
ATD	39.9	40.0								79.9
DEVELOPMENT		70.2	111.7	101.1	90.6	19.2				392.8
MISSION OPS & DATA ANALYSIS						20.0	79.0	71.0	184.3	354.3
LAUNCH SUPPORT			8.0	23.9	26.2	11.0				69.1
TRACKING & DATA SUPPORT				tbd	tbd	tbd	tbd	tbd	tbd	tbd
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)		110.2	119.7	125.0	116.8	50.2	79.0	71.0	184.3	896.1
(ESTIMATED CIVIL SERVICE FTEs)	(29)	(34)	(33)	(27)	(9)	(3)	(2)	(1)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	2.2	2.8	2.8	2.4	0.8	0.3	0.2	0.1		

Relativity Mission/Gravity Probe-B

The development of the Relativity mission began in 1993, after many years of studying mission design alternatives and developing the advanced technologies required for this mission to verify Einstein's theory of general relativity. The award of the spacecraft development contract was made in 1994. The scheduled launch date is October 2000, using a Delta II launch vehicle. This launch date coincides with the original baseline date for launch of the Relativity Mission. The FY 1999 budget forecast a March 2000 launch, assuming that the program would not consume its schedule reserves. In the past year, however, the project has encountered, and resolved, several technical problems which have resulted in the consumption of those reserves.

The estimates provided below include funding for the experiment development activities, a minimum of 16 months of mission operations, and the launch services. These estimates are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts for the definition phase studies carried out from FY 1985-87, but they do provide the amounts for the Shuttle Test of Relativity Experiment program initiated in FY 1988 and subsequently restructured into a ground test program only. The estimates also exclude the non-program-unique government facilities and general and administrative support used to carry out the research and development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	330.9	57.3	42.6	25.7	5.4					461.9
MISSION OPS & DATA ANALYSIS					9.1	6.3	4.1			19.5
LAUNCH SUPPORT	10.6	13.5	14.8	14.8						53.7
TRACKING & DATA SUPPORT							TBD			TBD
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	341.5	70.8	57.4	40.5	14.5	6.3	4.1			535.1
(ESTIMATED CIVIL SERVICE FTEs)	(90)	(8)	(10)	(7)						
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	5.6	0.7	0.8	0.6						

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)

The TIMED mission is the first science mission in the Solar Terrestrial Probes (STP) Program, and is part of NASA's initiative aimed at providing cost-efficient scientific investigation and more frequent access to space. TIMED will be developed for NASA by the Johns Hopkins University Applied Physics Laboratory (APL). The Aerospace Corporation, the University of Michigan, NASA's Langley Research Center with the Utah State University's Space Dynamics Laboratory, and the National Center for Atmospheric Research will provide instruments for the TIMED mission.

TIMED is scheduled for launch in May 2000 aboard a Med-Lite Class launch vehicle. TIMED began its 36-month C/D development period in April 1997. The budgetary estimates below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the amounts for the definition phase studies carried out from April 1996 to April 1997.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	25.9	55.7	37.8	9.9						129.3
MISSION OPS & DATA ANALYSIS				8.7	11.3	8.8	6.6	2.8		38.2
LAUNCH SUPPORT	4.4	8.7	11.5	6.1						30.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	30.3	64.4	49.3	24.7	11.3	8.8	6.6	2.8		198.2
(ESTIMATED CIVIL SERVICE FTEs)	(21)	(12)	(15)	(16)	(7)	(8)	(5)	(5)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	1.6	1.0	1.3	1.4	0.6	0.8	0.5	0.5		

The Explorer Program

The Explorer program consists of small to mid-sized spacecraft conducting investigations in all space physics and astrophysics disciplines. The program provides for frequent, relatively low-cost missions to be undertaken as funding availability permits within an essentially level overall funding profile for the program. The funding profile provided below covers the design and development phase, launch services, mission-unique tracking and data acquisition support, mission operations and data analysis. It does not include costs for the use of government facilities and general and administrative support required to implement the program. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
Far Ultraviolet Spectroscopy Explorer	105.5	38.4	26.5	13.4	14.4	7.0				205.2
Imager for Magnetospause-to-Aurora Global Explora	39.6	39.2	42.2	14.0	7.1	7.1	2.5	1.0		152.7
Microwave Anisotropy Probe	22.5	26.0	40.1	33.8	20.3	3.7	2.6			149.0
*SWAS, TRACE, WIRE	176.2	33.5	17.9	7.4	7.4	3.5	0.4			246.3
HESSI, GALEX, TWINS, BOLT (New SMEX)		25.5	57.8	45.0	26.3	8.7	8.7	5.5		177.5
*STEDI (SNOE, TERRIERS, CATSAT)	35.1	1.2	5.5	1.0	0.1					42.9
*HETE-II	1.4	7.5	7.2	1.5	1.5					19.1
*Planning & Future Developments		3.1	20.6	63.4	127.0	182.0	243.6	282.5	CONT	
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)		174.4	217.8	179.5	204.1	212.0	257.8	289.0	CONT	
(ESTIMATED CIVIL SERVICE FTEs)	(2,081)	(250)	(184)	(132)	(53)	(31)	(34)	(28)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)		20.5	15.5	11.8	4.9	3.0	3.4	3.0		

*Tracking estimate is not included

Far Ultraviolet Spectroscopic Explorer

Development on the Far Ultraviolet Spectroscopy Explorer (FUSE) began in FY 1996. The FUSE mission was restructured from a Delta-class explorer in order to reduce costs and accelerate the launch date from CY 2000 to November 1998. As a result of technical difficulties encountered, particularly with the spacecraft gyros, the launch date has been delayed until May 2000. FUSE is being managed by Johns Hopkins University, with contributions from the University of Colorado, the University of California-Berkeley, Orbital Sciences Corp., Canada and France.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	84.4	22.1	14.8							121.3
MISSION OPS & DATA ANALYSIS		0.3	10.6	13.4	14.4	7.0				45.7
LAUNCH SUPPORT	21.1	16.0	1.1							38.2
TOTAL	105.5	38.4	26.5	13.4	14.4	7.0				205.2

Imager for Magnetopause-to-Aurora Global Exploration

Development on the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) began in FY 1997. The IMAGE mission will use three-dimensional imaging techniques to study the global response of the Earth's magnetosphere to variations in the solar wind, the stream of electrified particles flowing out from the Sun. The magnetosphere is the region surrounding the Earth controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. Southwest Research Institute has been selected to develop the IMAGE mission. IMAGE is scheduled for launch in February 2000 aboard a Delta-7326 (Med-Lite Class ELV).

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	32.3	26.4	17.2	7.7						83.6
MISSION OPS & DATA ANALYSIS				4.6	7.1	7.1	2.5	1.0		22.3
LAUNCH SUPPORT	7.3	12.8	25.0	1.7						46.8
TOTAL	39.6	39.2	42.2	14.0	7.1	7.1	2.5	1.0		152.7

Microwave Anisotropy Probe

Development on the Microwave Anisotropy Probe (MAP) began in FY 1997. The MAP mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos. GSFC is developing the MAP instruments in cooperation with Princeton University. MAP will launch in November 2000 aboard a Delta-7326 (Med-Lite Class ELV).

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	21.1	19.8	18.8	18.2	10.4					88.3
MISSION OPS & DATA ANALYSIS				0.9	4.2	3.7	2.6			11.4
LAUNCH SUPPORT	1.4	6.2	21.3	14.7	5.7					49.3
TOTAL	22.5	26.0	40.1	33.8	20.3	3.7	2.6			149.0

Stratospheric Observatory for Infrared Astronomy

The initial development funding for the Stratospheric Observatory for Infrared Astronomy (SOFIA) was requested in the FY 1996 budget. This new airborne observatory will provide a significant increase in scientific capabilities over the Kuiper Airborne Observatory, which was retired in October, 1995. The SOFIA will be accommodated in a Boeing 747 and will feature a 2.5-meter infrared telescope to be provided by the German Space Agency (DARA). SOFIA will conduct scientific investigations at infrared and submillimeter wavelengths. The initial science flights for SOFIA are scheduled to occur in October 2001; however, delays in development of the German telescope assembly are currently expected to result in a slip of several months.

The budget estimates provided below are the amounts included in the Science, Aeronautics and Technology appropriation for this program. They do not include the costs of preliminary design studies carried out in previous years, the amounts being contributed by the international participants, or costs for the use of government facilities and general and administrative support used to carry out the research and development activities. A more detailed exposition of the program goals, objectives and activities is provided in the specific budget justification narrative for the Suborbital program within the Space Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	51.3	45.8	58.2	45.1	34.4	36.6				271.4
MISSION OPERATIONS							38.0	38.9	CONT.	CONT.
TOTAL EXCLUDING CIVIL SERVICE COSTS	51.3	45.8	58.2	45.1	34.4	36.6	38.0	38.9		
(ESTIMATED CIVIL SERVICE FTEs)	(83)	(38)	(51)	(40)	(20)	(20)	(20)	(20)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	6.2	3.1	4.3	3.6	1.8	1.9	2.0	2.1		

Discovery Missions

Discovery missions are planetary exploration missions designed with focused science objectives that can be met with limited resources. Total development costs are not to exceed $150 million in constant FY 1992 dollars, and development schedules are limited to three years or less. Three Discovery missions have been launched: NEAR in February 1996, Mars Pathfinder in December 1996 and Lunar Prospector in January 1998. In addition, there are two Discovery missions currently in development (Stardust and Genesis), and one in planning (CONTOUR). Other future Discovery missions will be undertaken after selection through a peer review process.

The budgetary estimates provided below are the amounts included in the specific budget justification for this program within the Space Science section in the Science, Aeronautics and Technology appropriation. Under the specific mission descriptions, see below, other direct program cost elements are included: the development of the spacecraft and experiments, one year of mission operations, the launch services, and unique tracking and data acquisition services. They do not include costs for the use of government facilities and general and administrative support required to implement the program. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
NEAR	176.7	11.2	14.6	8.8	0.2					211.5
LUNAR PROSPECTOR	57.0	4.7	2.2							63.9
STARDUST	94.3	56.2	25.8	3.5	3.7	3.7	5.0	4.0	13.8	210.0
GENESIS	0.8	41.0	82.9	50.2	18.3	6.9	7.0	3.3	3.5	213.9
CONTOUR	0.4		8.4	51.8	45.6	21.1	3.7	3.0	9.9	143.9
FUTURE MISSIONS		2.4	11.3	78.5	93.3	173.0	217.9	214.4		
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	329.2	115.5	145.2	192.8	161.1	204.7	233.6	224.7		
(ESTIMATED CIVIL SERVICE FTEs)	(54)	(15)	(21)	(18)	(17)	(16)	(10)	(10)	Cont.	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	3.9	1.2	1.8	1.6	1.6	1.5	1.0	1.1	Cont.	

Near-Earth Asteroid Rendezvous (NEAR)

The NEAR was approved as a new start in FY 1994 as one of the initial Discovery Program missions. The NEAR mission was conducted as an in-house effort at the Applied Physics Laboratory, with many subcontracted subsystems. The NEAR spacecraft will conduct a comprehensive study of the near-Earth asteroid 433 Eros, including its physical and geological properties and its chemical and mineralogical composition. The NEAR spacecraft was launched February 17, 1996 on a Delta II launch vehicle. The original opportunity to rendezvous with the asteroid in January 1999 was recently lost when the spacecraft failed to fire its main engine properly. However, a subsequent firing was successful, and NEAR will rendezvous with Eros in February 2000. The cost impact of extending the mission by 13 months has not yet been negotiated, and will be incorporated in future budget plans.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	124.9									124.9
MISSION OPS & DATA ANALYSIS	8.0	11.0	14.4	8.6						42.0
LAUNCH SUPPORT	43.5									43.5
TRACKING & DATA SUPPORT	0.3	0.2	0.2	0.2	0.2					1.1
TOTAL	176.7	11.2	14.6	8.8	0.2					211.5

Lunar Prospector

Lunar Prospector was selected as the third Discovery mission in FY 1995, and Phase C/D development started in the first quarter of FY 1996. The mission is designed to search for resources on the Moon, with special emphasis on the search for water in the shaded polar regions. Ames Research Center is managing the mission, and Lockheed Martin will provide the spacecraft, instruments, launch and operations. Launch on a Lockheed Launch Vehicle-II (LLV-II) occurred in January 1998, and the primary mission has been completed successfully. Launch costs are included in the development cost. Tracking and communications support are provided by the Deep Space Network.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	56.2	0.4								56.6
MISSION OPS & DATA ANALYSIS	0.8	4.3	2.2							7.3
TOTAL	57.0	4.7	2.2							63.9

Stardust

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory. The mission team completed the Phase B analysis, and Stardust was approved for implementation in October 1996. The mission is designed to gather samples of dust from the comet Wild-2 and return the samples to Earth for detailed analysis. The mission will also gather and return samples of interstellar dust that the spacecraft encounters during its trip through the Solar System to fly by the comet. Stardust will use a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, the spacecraft will carry three additional scientific instruments. An optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) is provided by Germany to perform basic compositional analysis of the samples while in flight; and a dust flux monitor will be used to sense particle impacts on the spacecraft. Stardust will be launched on the Med-Lite expendable launch vehicle in February 1999 with return of the samples to Earth in January 2006.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
PHASE A/B	9.6									9.6
DEVELOPMENT	65.7	42.3	9.8							117.8
MISSION OPS & DATA ANALYSIS			3.5	3.5	3.7	3.7	5.0	4.0	13.8	37.2
LAUNCH SUPPORT	19.0	13.9	12.5							45.4
TOTAL	94.3	56.2	25.8	3.5	3.7	3.7	5.0	4.0	13.8	210.0

Genesis

In October 1997 NASA selected Genesis as the fifth Discovery mission. The Genesis mission is designed to collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis. It is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA; JPL will provide the payload and project management, while the spacecraft will be provided by Lockheed Martin Astronautics of Denver, CO. Due for launch in January 2001, it will return the samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert in August 2003. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
PHASE A/B	0.3	11.1								11.4
DEVELOPMENT		20.3	65.1	33.2	7.3					125.9
MISSION OPS & DATA ANALYSIS					10.5	6.4	6.5	3.3	3.5	30.2
LAUNCH SUPPORT	0.5	9.6	17.8	17.0						44.9
TRACKING & DATA SUPPORT					0.5	0.5	0.5			1.5
TOTAL	0.8	41.0	82.9	50.2	18.3	6.9	7.0	3.3	3.5	213.9

Comet Nucleus Tour (CONTOUR)

In October 1997 NASA selected CONTOUR as the sixth Discovery mission. CONTOUR's goals are to dramatically improve our knowledge of key characteristics of comet nuclei and to assess their diversity. The spacecraft will leave Earth orbit, but stay relatively near Earth while intercepting at least three comets. The targets span the range from a very evolved comet (Encke) to a future "new" comet such as Hale-Bopp. CONTOUR builds on the exploratory results from the Halley flybys, and will extend the applicability of data obtained by NASA's Stardust and ESA's Rosetta to broaden our understanding of comets. The Principal Investigator is J. Veverka of Cornell University; the spacecraft and project management will be provided by the Johns Hopkins University Applied Physics Laboratory of Laurel, MD. Launch is expected in June 2002.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
PHASE A/B	0.4		8.4							8.8
DEVELOPMENT				34.9	26.0	8.2				69.1
MISSION OPS & DATA ANALYSIS						2.1	3.7	3.0	9.9	18.7
LAUNCH SUPPORT				16.9	19.6	10.8				47.3
TRACKING & DATA SUPPORT						TBD				TBD
TOTAL	0.4		8.4	51.8	45.6	21.1	3.7	3.0	9.9	143.9

Mars Surveyor Program

The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. The first mission in this program, the Mars Global Surveyor mission, was approved as a new start in FY 1994. The follow-on Mars Surveyor 98 Orbiter and Lander were approved in FY 1995. The Mars Surveyor '01 Orbiter and Lander are to enter development in FY 1998. Future small missions are targeted for launch in the launch windows that occur approximately every two years.

The budgetary estimates below are the amounts indicated in the budget justification within the Space Science section in the Science, Aeronautics and Technology appropriation. The specific write-ups for the Mars Global Surveyor and Mars 98 Orbiter/Lander missions include the amounts for the development of the spacecraft and instruments, two years of mission operations, and launch services. They do not include costs for the use of government facilities and general and administrative support used to carry out the program. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
MARS GLOBAL SURVEYOR	198.0	19.5	13.1	15.9	9.7	9.3	4.4			269.9
98 MARS ORBITER/LANDER	183.2	79.6	30.9	13.6	10.4	7.3	3.5			328.5
01 MARS ORBITER/LANDER		71.2	150.7	126.8	43.2	15.0	14.8			421.7
FUTURE MISSIONS	6.5	37.1	55.7	114.8	208.9	231.2	238.0	233.5	Cont.	1,125.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	387.7	207.4	250.4	271.1	272.2	262.7	260.7	233.5		2,145.7
(ESTIMATED CIVIL SERVICE FTEs)	(62)	(21)	(18)	(19)	(20)	(20)	(19)	(19)	(Cont.)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	4.5	1.7	1.5	1.7	1.8	1.9	1.9	2.0	Cont.	

Mars Global Surveyor

This mission will obtain a majority of the expected science return from the lost Mars Observer mission by flying a science payload comprised of spare Mars Observer instruments aboard a small, industry-developed spacecraft. Launch occurred in November 1996 on a Delta II launch vehicle, and MGS entered Mars orbit in September 1997. The funding estimates provided below do not include the previous expenditures on spare Mars Observer instruments or the amount recovered from the prime contractor after the Mars Observer failure.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	130.7									130.7
MISSION OPS & DATA ANALYSIS	14.7	19.5	13.1	15.9	9.7	9.3	4.4	3.0		89.6
LAUNCH SUPPORT	52.6									52.6
TOTAL	198.0	19.5	13.1	15.9	9.7	9.3	4.4	3.0		272.9

98 Mars Orbiter/Lander

The 98 Mars Orbiter and Lander are the first follow-on missions in the Mars Surveyor program. The Orbiter was launched on a Med-Lite launcher in December 1998, and the Lander was launched on a Med-Lite in January 1999. Lockheed Martin Aerospace, Denver, was selected competitively to develop these spacecraft. The Orbiter carries a color imager and a Pressure Modulater Infrared Radiometer (PMIRR), which was also a Mars Observer payload. The Lander carries a descent imager, a comprehensive volatiles and climate payload, and a Russian LIDAR atmospheric instrument.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	138.7	41.1	13.3							193.1
MISSION OPS & DATA ANALYSIS			8.7	13.2	10.1	7.3	3.5			42.8
LAUNCH SUPPORT	44.5	38.5	8.7							91.7
TRACKING & DATA SUPPORT			0.2	0.4	0.3					0.9
TOTAL	183.2	79.6	30.9	13.6	10.4	7.3	3.5			328.5

'01 Mars Orbiter/Lander

This mission will explore the ancient highlands of Mars to characterize the surface environment in terms of its geologic and aqueous history. The Mars 2001 Orbiter will include Gamma Ray Spectrometer (GRS), Thermal Emission Imaging System (THEMIS), and Mars Radiation Environment Experiment (MARIE). The Mars 2001 Lander will include a Pathfinder/Sojourner-type rover, as well as the Athena Precursor Experiment (APEX), Mars Descent Imager (MARDI), MARIE, Mars Environmental Compatibility Assessment (MECA), and Mars ISPP (In-situ Propellant Production) Precursor (MIP). This instrument complement meets the science requirements of the Office of Space Science, the Office of Human Spaceflight, and the Office of Life and Microgravity Sciences and Applications. The Orbiter and Lander are scheduled to launch in March and April of 2001, respectively, the Orbiter on a Delta 7425 from Vandenberg AFB, and the Lander on a Delta 7925 from Cape Canaveral.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT		67.0	110.7	85.9	18.4					282.0
MISSION OPS & DATA ANALYSIS					9.0	15.0	14.8	15.0		53.8
LAUNCH SUPPORT		4.2	40.0	40.9	15.8					100.9
TRACKING & DATA SUPPORT										
TOTAL		71.2	150.7	126.8	43.2	15.0	14.8	15.0		436.7

Future Surveyor Missions

The Mars Surveyor landers planned in future years -- 2003, 2005 and beyond -- will capitalize on the experience of the Mars Pathfinder lander mission launched in November 1996. The small orbiter to be launched in 2003 will draw on the experience of Mars Global Surveyor and carry other scientific instruments into orbit to complete Mars Global Surveyor's science missions. A Mars sample return mission is being considered for the FY 2005 opportunity.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	6.5	37.1	55.7	114.8	175.8	195.8	210.4	220.1	cont.	
MISSION OPS & DATA ANALYSIS							7.5	13.4	cont.	
LAUNCH SUPPORT					33.1	35.4	20.1		cont.	
TRACKING & DATA SUPPORT										
TOTAL	6.5	37.1	55.7	114.8	208.9	231.2	238.0	233.5		

Space Science New Millennium Spacecraft

The New Millennium program is an advanced development effort started in FY 1996 to demonstrate how complex scientific spacecraft--such as those required for planetary missions--can be built for lower mission costs and have short development times, while still possessing considerable scientific merit. The New Millennium Spacecraft program will enable the introduction of the latest technology advances into spacecraft for planetary and outer solar system explorations. The primary objectives of the program are to increase the performance capabilities of spacecraft and instruments while simultaneously reducing total costs of future science missions, thereby allowing more frequent flight opportunities even under the severe budget constraints of the future. In previous years, NASA and the Department of Defense have funded technology developments which offer extraordinary promise. This precursor work on technologies can now be demonstrated in a series of flight technology demonstration missions occurring at a rate of one every 1.5 years, with the initial flight launched in October 1998.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation. The program is designed as an ongoing program, and funding is included for development and launch of one mission per every one and one half years, beginning in 1998. Launches are generally targeted for small expendable launch vehicles. The budget estimate below does not include the costs for the government facilities and general and administrative support used to carry out the research and development activities. Additional information on the first two missions is provided later in this section. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEEP SPACE 1	77.0	63.9	13.8	1.2						155.9
DEEP SPACE 2	16.4	8.3	1.9	0.8						27.4
FUTURE MISSIONS INCLUDING PROGRAM COSTS		7.1	10.8	14.1	13.1	13.8	14.3	6.1		
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)		79.3	26.5	16.1	13.1	13.8	14.3	6.1		
(ESTIMATED CIVIL SERVICE FTEs)	(321)	(1)	(1)	(1)	(3)	(3)	(3)	(3)		
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	4.0	0.1	0.1	0.1	0.3	0.3	0.3	0.3		

Deep Space 1

Deep Space 1 was selected in FY 1996 as the first New Millennium Program mission. The technology to be validated will include solar electric propulsion, an advanced solar array, autonomous primary navigation, and miniature imaging camera spectrometer. Spectrum Astro was selected in FY 1996 to integrate the spacecraft. DS 1 launched in October, 1998 on a Med-Lite-class Delta launch vehicle, and has partially validated four of the five mission-defining technology demonstrations. These technologies will complete their validation by the end of FY 1999. The supplemental technology development line below contains funding for crosscutting technology development efforts previously managed by the Office of Space Access and Technology.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	64.3	30.9	4.1							99.3
SUPPLEMENTAL TECH DEV (included in Dev)	[13.3]	[1.6]								[14.9]
MISSION OPS & DATA ANALYSIS			9.6	1.2						10.8
LAUNCH SUPPORT	12.6	32.8								45.4
TRACKING & DATA SUPPORT	0.1	0.2	0.1							0.4
TOTAL	77.0	63.9	13.8	1.2						155.9

Deep Space 2

Deep Space 2 was selected in FY 1996 as the second of the series of missions under the New Millennium Program. DS 2 is designed to develop and validate technologies and systems required to deliver multiple small packages to the surface and/or subsurface of Mars using direct entry. Some of the technologies to be validated include power electronics, a microcontroller, flexible interconnects for system cabling and a sample/water experiment. DS 2 was attached to ("piggyback" on) the Mars 98 Lander, launched in January 1999.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT	16.4	7.9	1.5	0.4						26.2
SUPPLEMENTAL TECH DEV (included in Dev)	[2.3]	[1.0]								[3.3]
MISSION OPS & DATA ANALYSIS		0.4	0.4	0.4						1.2
ELV INTEGRATION (included in Dev)		[1.6]								[1.6]
TRACKING & DATA SUPPORT										
TOTAL	16.4	8.3	1.9	0.8						27.4

Space Technology - 3

ST-3 is an interferometry technology validation flight (formerly New Millennium Deep Space-3, included in the flight validation program) to demonstrate the concept of separated spacecraft interferometry. This 6-month flight demonstration, scheduled for launch in 2002, will utilize two spacecraft to validate precision formation flying and space interferometry. This activity has been transferred from the flight validation program to the Astronomical Search for Origins focused program since its purpose is to validate those technologies required for the Terrestrial Planet Finder mission.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT			18.1	12.2	6.2	13.8	6.8			57.1
MISSION OPS & DATA ANALYSIS			0.2	0.7	1.4	4.2				6.5
LAUNCH SUPPORT			9.5	12.5	14.8	13.3				50.1
TRACKING & DATA SUPPORT										
TOTAL			27.8	25.4	22.4	31.3	6.8			113.7

Space Technology - 4

ST-4, the Champollion/Comet Lander mission, will travel to, land on, and study a comet and (potentially) return a sample to Earth. Comets are essentially unaltered icy planetesimals left over from the formation of our solar system over four billion years ago. By studying comets, scientists can probe the beginnings of our solar system. This mission has been transferred from the Flight Validation Program (where it was referred to as the New Millennium Program Deep Space-4 mission), to the Advanced Deep Space Systems focused program because it is a solar system exploration mission.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	BTC	TOTAL
DEVELOPMENT			9.1	25.0	32.3	7.2	10.5			84.1
MISSION OPS & DATA ANALYSIS								3.0	6.0	9.0
LAUNCH SUPPORT					28.4	22.1	7.0			57.5
CHAMPOLLION SCIENCE PAYLOAD [in PL line]			2.3	12.5	28.1	28.9	3.3			75.1
TRACKING & DATA SUPPORT										
TOTAL			11.4	37.5	88.9	58.2	20.8	3.0	6.0	225.8

Earth Observing System

Before the Earth Observing System (EOS) was authorized in November 1990 in the FY 1991 budget as a new start, EOS planning had been in progress for over eight years. The EOS is key to achieving the objectives set forth in the Earth science program plan and the overall goal and scientific objectives of the interagency U.S. Global Change Research Program. EOS is an international science program, drawing upon the contributions of Europe (ESA), Canada. and Japan both in terms of spacecraft and instruments. This extraordinary collaboration is essential to reach the objective of providing comprehensive measurements of the nature of global climate change.

At its outset, the EOS program was based on the flights of two series of large platforms, in addition to platforms from Japan and ESA and instruments carried on Space Station Freedom. The initial estimates provided to Congress focused on the period through fiscal year 2000. The initial estimate of $18-2 1 billion included development, mission operations, data analysis, launch services. communications, construction of facilities and the amounts carried in the Space Station program for the polar platform's development. In the FY 1992 appropriations process, Congress directed NASA to modify the scope and cost of the program. The cost through FY 2000 was to be reduced by $5 billion. the FY 1993 funding level had to be reduced, and NASA was to examine the feasibility of using smaller platforms. In 1991, the program was restructured to employ five smaller flight series. In 1992, in response to the constrained budget environment, NASA further rescoped the program by implementing a common spacecraft approach for all flights after the first morning (*AM-*1) spacecraft, increasing reliance on the cooperative efforts of international and other government agencies, and adopting a build-to-cost approach for the first unit of a multiple instrument build. The estimated NASA funding through FY 2000 was further reduced to $8.0 billion in this effort.

In the FY 1995 budget process. the program cost estimate was further adjusted downward by approximately $0.9 billion, of which **$0.3** billion reflected an accounting transfer for small business innovative research out of individual programs into a common NASA account, and $0.1 billion reflected the change to lower-cost launch vehicles. The further reductions in program funding were addressed in 1994 through a program rebaselining activity. A number of small spacecraft were introduced into the program flight plans. In addition, alterations were made in flight phasing and accommodations were provided for a follow-on instrument to the enhanced thematic mapper being flown in 1999 on Landsat-7. Funding for the science investigations and data analysis was separated from the algorithms being developed to convert the instrument data into information. This change recognized the close relationship to similar science investigations and data analysis funded in the Earth Science research and analysis account. (The amounts budgeted for EOS science are shown in the table below.) In addition, it was decided to incorporate the development funding for the Landsat-7 into the EOS program in light of the integral ties between the two activities.

In the FY 1996 budget process, the amounts reflected the related program costs for Landsat-7 activities previously funded by the Department of Defense.

The 1997 Biennial Review completed the shift in planning for future missions that began in the 1995 "reshaping" exercise. Emerging science questions drive measurement requirements, which drive technology investments in advance of instrument selection and mission design. Mission design includes such options as purchase of science data from commercial systems and partnerships with other Federal agencies and international agencies. The result is a more flexible and less expensive, approach to acquiring Earth science data.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation except for the amount for the Space Station platform. The amounts below reflect the effects of the rescoping of the EOS program, the impacts of the ZBR, and the inclusion of the estimate for FY 2004. They do not include the costs of the non-program-unique government facilities and general and administrative support used to carry out the research and development activities. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Earth Science section.

(Budget Authority in Millions of Dollars)

Earth Observing System	Prior	1998	1999	2000	Subtotal Through FY 2000	2001	2002	2003	2004	Total Through FY 2004
MORNING	1,105.4	71.2	31.8	6.2	1,214.6	3.1				1,217.7
AFTERNOON	454.4	175.9	114.6	119.4	864.3	32.9				897.2
CHEMISTRY	95.7	110.4	130.4	124.7	461.2	93.3	61.5	18.4	7.0	641.4
SPECIAL SPACECRAFT	269.6	96.7	116.2	150.0	632.5	75.5	29.9	13.7	33.5	785.1
QUIKSCAT	35.0	37.9	10.8	1.1	84.8					84.8
LANDSAT 7	348.0	74.3	17.0	2.9	442.2	1.8	1.8	1.8	0.4	448.0
EOS FOLLOW-ON		3.9	4.5	53.9	62.3	194.9	259.8	308.6	315.0	1,140.6
ALGORITHM DEVELOPMENT	343.9	92.3	115.6	127.4	679.2	131.3	132.1	122.5	125.6	1,190.7
TECHNOLOGY INFUSION	76.6	91.9	90.2	77.6	336.3	102.8	120.8	107.0	113.3	780.2
EOSDIS	1,135.0	210.1	261.7	231.5	1,838.3	229.5	227.8	255.0	274.9	2,825.5
SUBTOTAL	3,863.6	964.6	892.8	894.7	6,615.7	865.1	833.7	827.0	869.7	10,011.2
PHASE B	41.0				41.0					41.0
SPACE STATION PLATFORM	104.0				104.0					104.0
EOS SCIENCE	131.3	41.4	46.4	76.0	295.1	69.9	69.8	68.1	71.0	573.9
LAUNCH SERVICES	238.6	39.4	4.2		282.2					282.2
CONSTRUCTION OF FACILITIES	96.7				96.7					96.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	4,475.2	1,045.4	943.4	970.7	7,434.7	935.0	903.5	895.1	940.7	11,109.0
(ESTIMATED CIVIL SERVICE FTEs)	(3,057)	(559)	(476)	(515)		(621)	(674)	(753)	(795)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M)	205.0	45.8	40.2	46.0		57.2	64.8	75.9	84.1	

EOS New Millennium Program and Technology Infusion

The New Millennium Program (NMP) and Technology Infusion budget reflects a commitment to develop new technology to meet the scientific needs of the next few decades and to reduce future EOS costs. The program objectives are to spawn "leap ahead" technology by applying the best capabilities available from several sources within the government, private industries and universities. The first mission EO-1, has been selected to demonstrate innovative technology to produce Landsat data. The Space-Readiness Coherent Lidar Experiment (Sparcle) is the second EO mission.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	TOTAL
EO-1 (INCLUDES LAUNCH SERVICES)	48.5	65.9	43.5	4.6	0.6				163.1
EO-2 SPARCLE (STS ATTACHED PAYLOAD)		6.8	6.1	2.0	0.8				15.7
NMP TECHNOLOGY & FUTURE FLIGHTS (INCLUDES LAUNCH SERVICES)	9.9	9.0	7.7	34.5	62.4	82.4	69.7	73.0	348.6
ADV. INFORMATION SYSTEMS TECH.			6.5	7.6	9.0	9.5	9.8	9.8	52.2
SENSOR & DETECTOR TECHNOLOGY	11.0	5.5	5.5	8.9	10.0	8.9	5.5	8.5	63.8
INSTRUMENT INCUBATOR	7.2	4.7	20.9	20.0	20.0	20.0	22.0	22.0	136.8
TOTAL EXCLUDING CIVIL SERVICE COSTS (SM)	76.6	91.9	90.2	77.6	102.8	120.8	107.0	113.3	780.2
(ESTIMATED CIVIL SERVICE FTEs)	(68)	(58)	(30)	(4)	(1)				
CIVIL SERVICE COMPENSATION ESTIMATE	5.1	4.8	2.5	0.4	0.1				

Earth Probes

The Earth Probes program consists of spacecraft and instrument development to address specific, highly-focused mission requirements in Earth science research. They are complementary to the scientific data-gathering activities carried out within the EOS program. The currently approved Earth probes are the Total Ozone Mapping Spectrometer (TOMS), and the Tropical Rainfall Measuring Mission. The Earth System Science Pathfinder missions will be funded to take advantage of the new technologies in spacecraft and instrument design being developed by other federal agencies and by NASA. The Experiments of Opportunity funding will accommodate opportunities to provide flight instruments and technologies on non-Earth science missions, foreign or domestic, or on airborne experiments. The Lewis and Clark missions were transferred from the Office of Space Access and Technology when that office was dissolved.

The budgetary estimates below represent funding included in the Science, Aeronautics and Technology appropriation. The program is designed as an ongoing program. The budget estimates immediately below do not include the estimated costs incurred by the international collaborators, mission operations, science costs, related funding included in the Earth Observing System program, NASA civil service work force salary and expenses, use of government facilities and general and administrative support used to carry out the research and development activities. A more detailed description of the program goals, objectives and activities is provided in the specific budget justification narrative for the program within the Earth Science section.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	TOTAL
TOTAL OZONE MAPPING SPECTROMETER (TOMS)	111.4	6.0	4.9	4.9	0.4				127.6
NASA SCATTEROMETER (NSCAT)	210.0								210.0
TROPICAL RAINFALL MEASURING MISSION (TRMM)	245.1	0.9							246.0
TRIANA		0.9	35.0	35.1	2.0	2.0			75.0
LEWIS & CLARK	129.0	1.4	0.1						130.5
UNIVERSITY CLASS EARTH SYSTEM SCIENCE (UNESS)				2.0	4.0	4.0	4.0	4.0	Continues
EARTH SYSTEM SCIENCE PATHFINDERS	15.0	22.8	62.2	75.2	117.5	127.1	119.3	110.5	Continues
EXPERIMENTS OF OPPORTUNITY		2.9	2.5	1.0	0.5	0.5	0.4	0.5	Continues
(ESTIMATED CIVIL SERVICE FTEs)	(840)	(65)	(56)	(57)	(43)	(41)	(42)	(42)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M	56.3	5.3	4.7	5.1	4.0	3.9	4.2	4.4	

Total Ozone Mapping Spectrometer

The TOMS Earth Probes project is a follow-on to the Total Ozone Mapping Spectrometer (TOMS) instrument flown with such great success on the Nimbus-7 spacecraft in 1978. A TOMS instrument was also flown on the Russian METEOR spacecraft in 1991. The TOMS program consists of a set of instruments (flight models 3, 4, 5) and one small spacecraft. Flight model 3 was launched on the TOMS Earth probe spacecraft on July 2, 1996. Flight model 4 was launched on the Japanese ADEOS spacecraft on August 17, 1996. The ADEOS-I spacecraft failed on June 30, 1997. Flight model 5 is currently planned for a cooperative mission with the Russian Space Agency.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	TOTAL
DEVELOPMENT	111.4	6.0	4.9	4.9	0.4				127.6
MISSION OPERATIONS	5.5	2.7	2.7	3.0	2.9	1.6	1.6		20.0
SCIENCE TEAMS	0.9	0.9	0.9	1.0	1.1	1.1	1.0	1.1	8.0
SELV	16.7								16.7
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	134.5	9.6	8.5	8.9	4.4	2.7	2.6	1.1	172.3
(ESTIMATED CIVIL SERVICE FTEs)	(145)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	
CIVIL SERVICE COMPENSATION ESTIMATE ($M	9.7	0.3	0.3	0.4	0.4	0.4	0.4	0.4	

Tropical Rainfall Measuring Mission

The Tropical Rainfall Measuring Mission (TRMM) was launched aboard the Japanese H-II vehicle November 27, 1997. The TRMM development began in FY 1992, after a four-year period of concept studies and preliminary mission definition. The TRMM objective is to obtain a minimum of three years of climatologically significant observations of tropical rainfall. TRMM data will be useful to understand the ocean-atmosphere coupling, especially in the development of El Niño events, which form in the tropics but whose effects are felt globally. The observatory spacecraft was built in-house at the Goddard Space Flight Center. The Japanese built a critical instrument, the Precipitation Radar. Two other instruments are being developed with TRMM program funding, the Visible and Infrared Scanner and TRMM Microwave Imager. In 1992, two EOS-funded instruments were added to the payload, the Clouds and Earth's Radiant Energy System (CERES) and the Lightning Imaging Sensor (LIS). The budget estimates provided below include the costs of accommodating these two instruments on the TRMM observatory. The EOS Data and Information System will have a specific capability for disseminating TRMM data.

(Budget Authority in Millions of Dollars)

	PRIOR	1998	1999	2000	2001	2002	2003	2004	TOTAL
DEVELOPMENT	245.1	0.9							246.0
EOS-FUNDED INSTRUMENTS/SCIENCE/DIS	[50.2]	[8.8]	[12.6]						[71.6]
MISSION OPERATIONS	0.8	10.6	10.9	11.0	9.7	2.2			45.2
SCIENCE TEAMS	2.1	11.2	14.3	14.4	14.9	4.6			61.5
RESEARCH & ANALYSIS-FUNDED SCIENCE	35.4								35.4
TOTAL EXCLUDING CIVIL SERVICE COSTS ($M)	283.4	22.7	25.2	25.4	24.6	6.8			388.1
(ESTIMATED CIVIL SERVICE FTEs)	(695)	(11)	(10)	(12)	(12)	(2)			
CIVIL SERVICE COMPENSATION ESTIMATE ($M	46.6	0.9	0.8	1.1	1.1	0.2			

SUMMARY OF BUDGET PLAN BY FUNCTION

	FY 1998	FY 1999	FY 2000
PERSONNEL AND RELATED COSTS	$1,592.3	$1,602.8	$1,646.9
TRAVEL	$44.4	$48.8	$51.7
RESEARCH OPERATIONS SUPPORT	$388.9	$469.6	$482.6
TOTAL PROGRAM PLAN	**$2,025.6**	**$2,121.2**	**$2,181.2**

DETAIL OF BUDGET PLAN BY FUNCTION

	FY 1998	FY 1999	FY 2000
		(Millions of Dollars)	
I. Personnel and related costs	$1,592.3	$1,602.8	$1,646.9
A. Compensation and benefits	$1,540.7	$1,557.9	$1,598.1
1. Compensation	$1,255.9	$1,282.3	$1,320.9
2. Benefits	$284.8	$275.6	$277.2
B. Supporting costs	$51.6	$44.9	$48.8
1. Transfer of personnel	$12.0	$10.7	$9.5
2. Investigative services	$2.5	$1.5	$1.7
3. Personnel training	$37.1	$32.7	$37.6
II. Travel	$44.4	$48.8	$51.7
A. Program travel	$28.0	$30.4	$32.5
B. Scientific and technical development travel	$5.1	$5.4	$5.7
C. Management and operations travel	$11.3	$13.0	$13.5
III. Research operations support	$388.9	$469.6	$482.6
A. Facilities services	$124.1	$127.3	$130.5
B. Technical services	$147.2	$189.3	$206.5
C. Management and operations	$117.6	$153.0	$145.6
Total	$2,025.6	$2,121.2	$2,181.2

DISTRIBUTION OF BUDGET PLAN BY FUNCTION BY INSTALLATION
(MILLIONS OF DOLLARS)

FUNCTION	TOTAL NASA	JSC	KSC	MSFC	SSC	GSFC	ARC	DFRC	LARC	GRC	HQS
PERSONNEL AND RELATED COSTS											
FY 1998	1,592.3	284.0	154.0	229.2	18.9	270.8	135.2	44.7	188.0	164.9	102.6
FY 1999	1,602.8	287.1	149.7	227.6	20.5	276.3	135.9	49.9	188.3	165.0	102.5
FY 2000	1,646.9	287.5	149.2	227.0	21.3	289.3	142.4	53.3	199.6	171.3	106.0
TRAVEL											
FY 1998	44.4	8.1	4.0	6.1	0.6	6.8	3.5	1.5	4.0	3.4	6.4
FY 1999	48.8	8.8	5.0	6.4	0.6	7.5	3.3	1.4	4.9	3.7	7.1
FY 2000	51.7	9.4	5.4	6.6	0.8	8.1	3.8	1.5	4.8	3.9	7.4
RESEARCH OPERATIONS SUPPORT											
FY 1998	388.9	40.1	72.5	46.9	21.3	49.9	28.3	8.6	22.3	24.6	74.4
FY 1999	469.6	48.2	78.4	54.9	25.7	53.4	29.9	7.1	25.0	27.8	119.2
FY 2000	482.6	43.7	79.9	52.7	27.6	56.6	28.9	6.1	20.0	24.7	142.4
TOTAL											
FY 1998	2,025.6	332.2	230.5	282.2	40.8	327.5	167.0	54.8	214.3	192.9	183.4
FY 1999	2,121.2	344.1	233.1	288.9	46.8	337.2	169.1	58.4	218.2	196.5	228.8
FY 2000	2,181.2	340.6	234.5	286.3	49.7	354.0	175.1	60.9	224.4	199.9	255.8

SUMMARY OF BUDGET PLAN BY INSTALLATION
(MILLIONS OF DOLLARS)

	FY 1998	FY 1999	FY 2000
JOHNSON SPACE CENTER	$332.2	$344.1	$340.6
KENNEDY SPACE CENTER	$230.5	$233.1	$234.5
MARSHALL SPACE FLIGHT CENTER	$282.2	$288.9	$286.3
STENNIS SPACE CENTER	$40.8	$46.8	$49.7
AMES RESEARCH CENTER	$167.0	$169.1	$175.1
DRYDEN FLIGHT RESEARCH CENTER	$54.8	$58.4	$60.9
LANGLEY RESEARCH CENTER	$214.3	$218.2	$224.4
GLENN RESEARCH CENTER	$192.9	$196.5	$199.9
GODDARD SPACE FLIGHT CENTER	$327.5	$337.2	$354.0
HEADQUARTERS	$183.4	$228.8	$255.8
AGENCY TOTAL	$2,025.6	$2,121.2	$2,181.2

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY INSTALLATION

	FY 1998	FY 1999	FY 2000
Johnson Space Center	3,147	2,992	2,819
Kennedy Space Center	1,869	1,784	1,633
Marshall Space Flight Center	2,822	2,690	2,525
Stennis Space Center	244	260	260
Goddard Space Flight Center	3,338	3,351	3,304
Ames Research Center	1,478	1,457	1,457
Dryden Flight Research Center	558	636	634
Langley Research Center	2,420	2,389	2,374
Glenn Research Center	2,074	2,003	1,983
Headquarters	974	983	981
Total, full-time equivalents	**18,924**	**18,545**	**17,970**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

	FY 1998	FY 1999	FY 2000
Space station	2,172	2,560	2,575
U.S./Russian cooperative program	32	27	15
Space shuttle	2,341	2,172	2,043
Payload and utilization operattions	533	324	306
Space science	1,871	1,865	1,787
Life and microgravity sciences	601	529	512
Mission to Planet Earth	1,560	1,496	1,518
Aeronautics research and technology	3,235	3,126	3,018
Advanced space transportation technology	1,078	1,037	1,094
Commercial technology programs	181	159	157
Academic programs	37	35	33
Mission communication services	296	283	223
Space communications services	91	108	93
Safety, reliability and quality assurance	128	110	102
Construction of facilities	120	128	123
Subtotal, direct full-time equivalents	**14,276**	**13,959**	**13,599**
Program management (Headquarters)	47	46	44
Center management and operations	4,601	4,540	4,327
Total, full-time equivalents	**18,924**	**18,545**	**17,970**

(

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

JOHNSON SPACE CENTER

	FY 1998	FY 1999	FY 2000
Space station	1,144	1,269	1,180
U.S./Russian cooperative program	16	12	0
Space shuttle	1,070	1,055	995
Payload and ELV Support	187	8	7
Space science	45	27	27
Life and microgravity sciences	126	110	110
Earth Sciences	0	0	0
Aeronautics and Space Transportation Technology	0	0	0
Advanced space transportation program	6	6	6
Commercial technology programs	13	11	11
Academic programs	7	5	5
Mission communication services	35	33	33
Space communications services	2	2	2
Safety, reliability and quality assurance	2	2	2
Construction of facilities	26	17	14
Subtotal, direct full-time equivalents	**2,679**	**2,557**	**2,392**
Program management (Headquarters)	0	0	0
Center management and operations	468	435	427
Total, full-time equivalents	**3,147**	**2,992**	**2,819**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

KENNEDY SPACE CENTER

	FY 1998	FY 1999	FY 2000
Space station	322	352	346
U.S./Russian cooperative program	0	0	0
Space shuttle	767	730	699
Payload and ELV Support	231	217	211
Space science	0	0	0
Life and microgravity sciences	19	16	16
Earth Sciences	0	0	0
Aeronautics and Space Transportation Technology	0	0	0
Advanced space transportation program	18	10	11
Commercial technology programs	12	15	13
Academic programs	0	0	0
Mission communication services	0	0	0
Space communications services	0	0	0
Safety, reliability and quality assurance	18	21	17
Construction of facilities	3	3	3
Subtotal, direct full-time equivalents	**1,390**	**1,364**	**1,316**
Program management (Headquarters)	0	0	0
Center management and operations	479	420	317
Total, full-time equivalents	**1,869**	**1,784**	**1,633**

(

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

MARSHALL SPACE FLIGHT CENTER

	FY 1998	FY 1999	FY 2000
Space station	493	561	596
U.S./Russian cooperative program	13	15	15
Space shuttle	394	325	301
Payload and ELV Support	12	11	6
Space science	302	269	179
Life and microgravity sciences	156	155	190
Earth Sciences	104	94	74
Aeronautics and Space Transportation Technology	0	0	0
Advanced space transportation program	603	555	558
Commercial technology programs	66	45	45
Academic programs	10	10	9
Mission communication services	1	0	0
Space communications services	11	17	8
Safety, reliability and quality assurance	10	11	9
Construction of facilities	16	32	12
Subtotal, direct full-time equivalents	**2,191**	**2,100**	**2,002**
Program management (Headquarters)	0	0	
Center management and operations	631	590	523
Total, full-time equivalents	**2,822**	**2,690**	**2,525**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

STENNIS SPACE CENTER

	FY 1998	FY 1999	FY 2000
Space station	0	0	0
U.S./Russian cooperative program	0	0	0
Space shuttle	34	30	21
Payload and ELV Support	0	0	0
Space science	0	0	0
Life and microgravity sciences	0	0	0
Earth Sciences	22	33	33
Aeronautics and Space Transportation Technology	0	1	0
Advanced space transportation program	46	42	33
Commercial technology programs	3	3	3
Academic programs	4	5	5
Mission communication services	0	0	0
Space communications services	0	0	0
Safety, reliability and quality assurance	1	2	2
Construction of facilities	33	34	52
Subtotal, direct full-time equivalents	**143**	**150**	**149**
Program management (Headquarters)	0	0	0
Center management and operations	101	110	111
Total, full-time equivalents	**244**	**260**	**260**

(

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

GODDARD SPACE FLIGHT CENTER

	FY 1998	FY 1999	FY 2000
Space station	0	0	0
U.S./Russian cooperative program	0	0	0
Space shuttle	4	4	4
Payload and ELV Support	50	56	56
Space science	1,011	1,045	1,045
Life and microgravity sciences	0	0	0
Earth Sciences	1,070	981	1,024
Aeronautics and Space Transportation Technology	12	4	0
Advanced space transportation program	0	0	0
Commercial technology programs	22	23	23
Academic programs	0	0	0
Mission communication services	186	180	120
Space communications services	70	78	72
Safety, reliability and quality assurance	21	8	7
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	**2,446**	**2,379**	**2,351**
Program management (Headquarters)	0	0	0
Center management and operations	892	972	953
Total, full-time equivalents	**3,338**	**3,351**	**3,304**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

AMES RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	37	55	76
U.S./Russian cooperative program	0	0	0
Space shuttle	0	0	0
Payload and ELV Support	0	0	0
Space science	175	172	173
Life and microgravity sciences	89	72	54
Earth Sciences	45	44	44
Aeronautics and Space Transportation Technology	657	662	637
Advanced space transportation program	69	66	86
Commercial technology programs	1	1	1
Academic programs	2	2	2
Mission communication services	0	0	0
Space communications services	0	0	0
Safety, reliability and quality assurance	10	10	9
Construction of facilities	25	25	25
Subtotal, direct full-time equivalents	**1,110**	**1,109**	**1,107**
Program management (Headquarters)	0	0	0
Center management and operations	368	348	350
Total, full-time equivalents	**1,478**	**1,457**	**1,457**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

DRYDEN FLIGHT RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	0	20	30
U.S./Russian cooperative program	0	0	0
Space shuttle	26	9	9
Payload and ELV Support	0	0	0
Space science	0	0	0
Life and microgravity sciences	0	0	0
Earth Sciences	30	39	39
Aeronautics and Space Transportation Technology	283	326	336
Advanced space transportation program	77	93	90
Commercial technology programs	4	4	4
Academic programs	0	0	0
Mission communication services	19	19	19
Space communications services	0	0	0
Safety, reliability and quality assurance	12	1	1
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	**451**	**511**	**528**
Program management (Headquarters)	0	0	0
Center management and operations	107	125	106
Total, full-time equivalents	**558**	**636**	**634**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

LANGLEY RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	8	11	17
U.S./Russian cooperative program	0	0	0
Space shuttle	2	0	0
Payload and ELV Support	40	28	22
Space science	59	74	85
Life and microgravity sciences	7	7	0
Earth Sciences	239	265	271
Aeronautics and Space Transportation Technology	1,313	1,250	1,236
Advanced space transportation program	148	148	167
Commercial technology programs	33	33	33
Academic programs	0	0	0
Mission communication services	0	0	0
Space communications services	0	11	11
Safety, reliability and quality assurance	2	4	4
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	**1,851**	**1,831**	**1,846**
Program management (Headquarters)	0	0	0
Center management and operations	569	558	528
Total, full-time equivalents	**2,420**	**2,389**	**2,374**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM

GLENN RESEARCH CENTER

	FY 1998	FY 1999	FY 2000
Space station	153	274	318
U.S./Russian cooperative program	0	0	0
Space shuttle	22	0	0
Payload and ELV Support	9	0	0
Space science	188	187	187
Life and microgravity sciences	171	135	108
Earth Sciences	17	7	0
Aeronautics and Space Transportation Technology	926	846	772
Advanced space transportation program	106	112	138
Commercial technology programs	17	14	14
Academic programs	5	4	3
Mission communication services	50	51	51
Space communications services	5	0	0
Safety, reliability and quality assurance	10	8	8
Construction of facilities	0	0	0
Subtotal, direct full-time equivalents	**1,679**	**1,638**	**1,599**
Program management (Headquarters)	0	0	0
Center management and operations	395	365	384
Total, full-time equivalents	**2,074**	**2,003**	**1,983**

DISTRIBUTION OF FULL-TIME EQUIVALENT (FTE) WORKYEARS BY PROGRAM
NASA HEADQUARTERS

	FY 1998	FY 1999	FY 2000
Space station	15	18	12
U.S./Russian cooperative program	3	0	0
Space shuttle	22	19	14
Payload and ELV Support	4	4	4
Space science	91	91	91
Life and microgravity sciences	33	34	34
Earth Sciences	33	33	33
Aeronautics and Space Transportation Technology	44	37	37
Advanced space transportation program	5	5	5
Commercial technology programs	10	10	10
Academic programs	9	9	9
Mission communication services	5	0	0
Space communications services	3	0	0
Safety, reliability and quality assurance	42	43	43
Construction of facilities	17	17	17
Subtotal, direct full-time equivalents	**336**	**320**	**309**
Program management (Headquarters)	47	46	44
Center management and operations	591	617	628
Total, full-time equivalents	**974**	**983**	**981**

DETAIL OF PERMANENT POSITIONS

	FY 1998	FY 1999	FY 2000
Executive level II	1	1	1
Executive level IV	2	2	2
Subtotal	3	3	3
ES-6	50	50	50
ES-5	109	109	109
ES-4	167	167	167
ES-3	70	70	70
ES-2	62	62	62
ES-1	47	47	47
Subtotal	505	505	505
CA	1	1	1
SL/ST	61	60	59
GS-15	2236	2184	2131
GS-14	3496	3414	3332
GS-13	6086	5943	5801
GS-12	1862	1818	1775
GS-11	1197	1169	1141
GS-10	258	252	246
GS-9	443	433	422
GS-8	241	235	230
GS-7	605	591	577
GS-6	533	521	508
GS-5	93	91	89
GS-4	16	16	15
GS-3	4	4	4
GS-2	0	1	1
Subtotal	17,132	16,732	16,331
Special ungraded positions established by NASA Administrator	25	25	25
Ungraded positions	355	355	355
Total permanent positions	18,020	17,620	17,219
Unfilled positions, EOY	0	0	0
Total, permanent employment, EOY	18,020	17,620	17,219

PERSONNEL SUMMARY

	FY 1998	FY 1999	FY 2000
Average GS/GM grade	12.5	12.5	12.5
Average ES salary	$118,776	$121,450	$124,185
Average GS/GM salary	$64,477	$66,798	$69,737
Average salary of special ungraded positions established by NASA Administrator	$92,047	$95,361	$99,557
Average salary of ungraded positions	$44,619	$46,225	$48,259

CENTER LOCATIONS AND CAPITAL INVESTMENT

JOHNSON SPACE CENTER - The Lyndon B. Johnson Space Center is located 20 miles southeast of Houston, Texas. NASA owns 1,618 acres of land at the Houston site and uses another 60,552 at the White Sands Test Facility, Las Cruces, New Mexico. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $2,720,153,000 as of September 30, 1998.

KENNEDY SPACE CENTER - The Kennedy Space Center is located 50 miles east of Orlando, Florida. NASA owns 82,943 acres and uses launch facilities at Cape Canaveral Air Station and Vandenberg Air Force Base. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $1,592,393,000 as of September 30, 1998.

MARSHALL SPACE FLIGHT CENTER - The Marshall Space Flight Center is located within the U.S. Army's Redstone Arsenal at Huntsville, Alabama. MSFC also manages operation at the Michoud Assembly 15 miles east of New Orleans, Louisiana and the Slidell Computer Complex in Slidell, Louisiana. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $3,035,495,000 as of September 30, 1998.

STENNIS SPACE CENTER - The Stennis Space Center is located approximately 50 miles northeast of New Orleans, Louisiana. NASA owns 20,663 acres and has easements covering an additional 118,284 acres. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $360,186,000 as of September 30, 1998.

GODDARD SPACE FLIGHT CENTER - The Goddard Space Flight Center is located 15 miles northeast of Washington, D.C. at Greenbelt, Maryland. NASA owns 1,121 acres at this location and an additional 6,176 acres at the Wallops Flight Facility in Wallops Island, Virginia. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $2,563,817,000 as of September 30, 1998.

AMES RESEARCH CENTER - The Ames Research Center is located south of San Francisco on Moffett Field, California. NASA owns 447.5 acres at the Moffett Field location. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $915,036,000 as of September 30, 1998.

DRYDEN FLIGHT RESEARCH CENTER - The Dryden Flight Research Center is 65 air miles northeast of Los Angeles. Dryden is located at the north end of Edwards Air Force Base on 838 acres of land under a permit from the Air Force. The total replacement cost at Dryden, including fixed assets in progress and contractor-held facilities at various locations, as of September 30, 1998 was $388,775,000.

LANGLEY RESEARCH CENTER - The Langley Research Center is adjacent to Langley Air Force Base which is located between Williamsburg and Norfolk at Hampton, Virginia. NASA owns 788 acres and has access to 3,276 acres. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets was $1,053,165,000 as of September 30, 1998.

GLENN RESEARCH CENTER – formerly known as the Lewis Research Center, this center occupies two sites; the main site is in Cleveland, Ohio, adjacent to Cleveland-Hopkins Airport; the second site is the Plum Brook Station located south of Sandusky, Ohio, and 50 miles west of Cleveland. NASA owns 6,805 acres and leases an additional 14 acres at the Cleveland location. The total replacement cost including land, buildings, structures and facilities, equipment, and other fixed assets at both locations was $617,065,000 as September 30, 1998.

NASA HEADQUARTERS - NASA Headquarters is located at Two Independence Square, 300 E St. SW, Washington, D.C. and occupies other buildings in the District of Columbia, Maryland, and Virginia.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 2000

SUMMARY OF CONSULTING SERVICES ESTIMATES

NASA uses paid experts and consultants to provide advice and expert input in addition to or beyond that available from its in-house civil service workforce. Management controls are established which assure that before entering into either consultant services arrangement with an individual that there is ample justification presented and the action is approved at top management levels.

NASA hires experts and consultants to provide expert advice and input on the selection of experiments for future space missions. The use of these experts and consultants, in addition to NASA civil service personnel, provides the agency with an independent view that assures the selection of experiments likely to have the greatest scientific merit. Other individuals are employed to provide independent looks at technical and functional problems in order to give top management the widest possible range of views before making major decisions.

	FY 1998	FY 1999	FY 2000
Number of Experts and Consultants	309	300	300
Annual FTE Usage	4	4	4
Average Annual Salary	$89,523	$90,000	$90,500
Total Salary and Benefits Costs	$405,600	$418,000	$501,600
Travel Costs	$594,000	$612,000	$630,000
Total Costs	$999,600	$1,030,000	$1,131,600

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
TOTAL NASA

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	1,255,926	1,282,353	1,320,900
12	PERSONNEL BENEFITS (CIVIL + PCS)	264,326	271,585	274,200
13	BENEFITS TO FORMER PERSONNEL	29,948	12,936	10,700
21	TRAVEL & TRANSP OF PERSONS	44,385	48,800	51,700
22	TRANSPORTATION OF THINGS	2,482	1,790	1,800
25	OTHER SERVICES	428,519	503,736	521,900
25	OTHER SERVICES (sal/bene + tvl)	39,619	34,136	39,300
25	OTHER SERVICES (ros)	388,900	469,600	482,600
		2,025,586	2,121,200	2,181,200

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
JOHNSON SPACE CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	226,361	231,197	231,746
12	PERSONNEL BENEFITS (CIVIL + PCS)	46,602	46,769	48,126
13	BENEFITS TO FORMER PERSONNEL	4,408	4,835	2,637
21	TRAVEL & TRANSP OF PERSONS	8,098	8,830	9,400
22	TRANSPORTATION OF THINGS	923	0	0
25	OTHER SERVICES	45,767	52,499	48,691
25	OTHER SERVICES (sal/bene + tvl)	5,667	4,299	4,991
25	OTHER SERVICES (ros)	40,100	48,200	43,700
		332,159	344,130	340,600

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
KENNEDY SPACE CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	117,533	118,288	117,898
12	PERSONNEL BENEFITS (CIVIL + PCS)	30,243	24,971	24,522
13	BENEFITS TO FORMER PERSONNEL	3,990	2,541	3,071
21	TRAVEL & TRANSP OF PERSONS	3,965	4,950	5,400
22	TRANSPORTATION OF THINGS	267	240	261
25	OTHER SERVICES	74,509	82,060	83,348
25	OTHER SERVICES (sal/bene + tvl)	2,009	3,660	3,448
25	OTHER SERVICES (ros)	72,500	78,400	79,900
		230,507	233,050	234,500

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
MARSHALL SPACE FLIGHT CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	179,880	178,813	178,435
12	PERSONNEL BENEFITS (CIVIL + PCS)	39,301	39,360	38,840
13	BENEFITS TO FORMER PERSONNEL	4,596	5,250	4,746
21	TRAVEL & TRANSP OF PERSONS	6,127	6,360	6,600
22	TRANSPORTATION OF THINGS	177	0	0
25	OTHER SERVICES	52,127	59,077	57,679
25	OTHER SERVICES (sal/bene + tvl)	5,227	4,177	4,979
25	OTHER SERVICES (ros)	46,900	54,900	52,700
		282,208	288,860	286,300

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
STENNIS SPACE CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	14,547	16,005	17,070
12	PERSONNEL BENEFITS (CIVIL + PCS)	3,707	4,195	3,910
13	BENEFITS TO FORMER PERSONNEL	218	0	0
21	TRAVEL & TRANSP OF PERSONS	579	640	800
22	TRANSPORTATION OF THINGS	97	0	0
25	OTHER SERVICES	21,657	26,000	27,920
25	OTHER SERVICES (sal/bene + tvl)	357	300	320
25	OTHER SERVICES (ros)	21,300	25,700	27,600
		40,805	46,840	49,700

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
AMES RESEARCH CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	107,200	109,640	114,327
12	PERSONNEL BENEFITS (CIVIL + PCS)	21,774	23,125	23,520
13	BENEFITS TO FORMER PERSONNEL	2,821	0	0
21	TRAVEL & TRANSP OF PERSONS	3,513	3,350	3,800
22	TRANSPORTATION OF THINGS	0	550	490
25	OTHER SERVICES	31,675	32,485	32,964
25	OTHER SERVICES (sal/bene + tvl)	3,375	2,585	4,064
25	OTHER SERVICES (ros)	28,300	29,900	28,900
		166,983	169,150	175,100

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
LANGLEY RESEARCH CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	149,349	152,989	162,440
12	PERSONNEL BENEFITS (CIVIL + PCS)	29,730	31,618	32,157
13	BENEFITS TO FORMER PERSONNEL	4,674	0	0
21	TRAVEL & TRANSP OF PERSONS	3,999	4,870	4,800
22	TRANSPORTATION OF THINGS	258	170	129
25	OTHER SERVICES	26,286	28,523	24,874
25	OTHER SERVICES (sal/bene + tvl)	3,986	3,523	4,874
25	OTHER SERVICES (ros)	22,300	25,000	20,000
		214,296	218,170	224,400

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
GLENN RESEARCH CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	130,613	132,637	137,029
12	PERSONNEL BENEFITS (CIVIL + PCS)	27,033	29,306	29,785
13	BENEFITS TO FORMER PERSONNEL	3,338	0	0
21	TRAVEL & TRANSP OF PERSONS	3,426	3,700	3,900
22	TRANSPORTATION OF THINGS	47	0	102
25	OTHER SERVICES	28,498	30,857	29,085
25	OTHER SERVICES (sal/bene + tvl)	3,898	3,057	4,385
25	OTHER SERVICES (ros)	24,600	27,800	24,700
		192,955	196,500	199,900

COST ESTIMATES:

A. Dryden Flight Research Center (DFRC)	$600,000
1. Remediation of Soil/Groundwater Contamination	600,000
B. Glenn Research Center (GRC)	$2,550,000
1. Remediation of UST Sites. PBS	1,000,000
2. Remediation Activities at Operable Units, PBS	650,000
3. Plum Brook Reactor Decommissioning Activities	900,000
C. Jet Propulsion Laboratory (JPL)	$4,700,000
1. Remediation of Arroyo Seco Groundwater Contamination	4,700,000
D. Johnson Space Center (JSC)	$1,300,000
1. Environmental Assessment/Cleanup for NASA Industrial Plant. Downey	250,000
2. Storm/Sanitary Cross Connections Compliance	400,000
3. Closure of Treatment Systems, B410 & B223	650,000
E. Kennedy Space Center (KSC)	$6,020,000
1. Remediation of Launch Complex 34	1,200,000
2. Remediation of Hydrocarbon Bum Facility	1,000,000
3. Remediation of Central Heating Plant	600,000
4. Remediation of Components Cleaning Facility Laboratory. Phase 2	1,000,000
5. Interim Remediation of Crawler Park Sites, West	400,000
6. Remediation of Contractor Heavy Equipment Area	670,000
7. Remediation of Hypergol Support Building, M7-1061	150,000
8. Restoration of Wetlands and Scrub Habitat, Phase 3	600,000
9. Various Interim Remedial Actions, Various Locations	400,000
F. Marshall Space Flight Center (MSFC)	$6,825,000
1. CERCLA Investigation and Cleanup	5,625,000
2. RCRA Investigation and Cleanup, Santa Susana Field Laboratory (SSFL)	500,000
3. Sewer System Rerouting and Compliance Modifications	700,000
G. Michoud Assembly Facility (MAF)	$1,250,000
1. Remediation Activities. Various Locations	1,250,000

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
GODDARD SPACE FLIGHT CENTER

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	217,480	222,716	234,337
12	PERSONNEL BENEFITS (CIVIL + PCS)	43,927	47,783	47,539
13	BENEFITS TO FORMER PERSONNEL	4,413	0	0
21	TRAVEL & TRANSP OF PERSONS	6,825	7,540	8,100
22	TRANSPORTATION OF THINGS	303	226	272
25	OTHER SERVICES	54,586	58,975	63,752
25	OTHER SERVICES (sal/bene + tvl)	4,686	5,575	7,152
25	OTHER SERVICES (ros)	49,900	53,400	56,600
		327,534	337,240	354,000

(

OBJECT CLASSIFICATION (FY 2000 CONGRESSIONAL BUDGET)
(THOUSANDS OF DOLLARS)
NASA HEADQUARTERS

	DIRECT OBLIGATIONS	FY 1998	FY 1999	FY 2000
11	PERSONNEL COMPENSATION	77,038	79,900	84,813
12	PERSONNEL BENEFITS (CIVIL + PCS)	14,402	15,851	16,868
13	BENEFITS TO FORMER PERSONNEL	1,489	310	246
21	TRAVEL & TRANSP OF PERSONS	6,390	7,140	7,400
22	TRANSPORTATION OF THINGS	148	450	480
25	OTHER SERVICES	83,961	125,189	145,993
25	OTHER SERVICES (sal/bene + tvl)	9,561	5,989	3,593
25	OTHER SERVICES (ros)	74,400	119,200	142,400
		183,428	228,840	255,800

FTE CHARTS BY MAJOR ORGANIZATION TO BE SUPPLIED LATER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHANGES FROM FY 1999 BUDGET ESTIMATE TO FY 1999 CURRENT ESTIMATE

(Dollars in Millions)

	NASA Request	Appropriation Action Additions	Reductions	Transfers	Appropriated Budget	NASA Program Changes	12/22/98 Op Plan
Human Space Flight	**5,511.0**			**-31.0**	**5,480.0**	--	**5,480.0**
Space Station	2,270.0				2,267.7	+37.0	2,304.7
Space Shuttle	3,059.0				3,030.3	-32.0	2,998.3
Payload & Utilization Ops	182.0				182.0	-5.0	177.0
Transfer to Mission Supt				-31.0			
Sci, Aero & Tech	**5,457.4**	**+242.8**	**-46.3**	--	**5,653.9**	--	**5,653.9**
Space Science	2,058.4	+82.0	-21.2		2,119.2		2,119.2
Aero-Space Tech	1,305.0	+47.8	-13.9		1,338.9		1,338.9
Life & Micro-G Science	242.0	+21.5			263.5		263.5
Academic Programs	100.0	+38.5			138.5		138.5
Mission Comm Services	380.0				380.0		380.0
Earth Science	1,372.0	+53.0	-11.2		1,413.8		1,413.8
Mission Support	**2,476.6**	**+3.5**		**+31.0**	**2,511.1**	--	**2,511.1**
SR&QA	35.6				35.6		35.6
Space Commun Svces	177.0				185.8		185.8
R&PM	2,099.0				2,121.2		2,121.2
Construc of Facil	165.0	+3.5			168.5		168.5
Transfer from HSF				+31.0			
Inspector General	**20.0**			--	**20.0**	--	**20.0**
TOTAL NASA	**13,465.0**	**+246.3**	**-46.3**	**0.0**	**13,665.0**	**0.0**	**13,665.0**

	FY 99 President's Budget	Gen'l Reduc-tions	Approp. Adjust-Ments	Congress-ional Adds	FY99 Appropr. Budget	11/13/98 AXAF/Triana Changes	12/22/98 Changes	Initial FY99 Op Plan
HUMAN SPACE FLIGHT	**5,511.0**		**-31.0**		**5,480.0**		**0.0**	**5,480.0**
SPACE STATION	**2,270.0**		**-2.3**		**2,267.7**		**+37.0**	**2,304.7**
Development	1,055.5				1,055.5		+253.3	1,308.8
Operations	840.3		-2.3		838.0		-231.6	606.4
Research Program	374.2				374.2		-37.7	336.5
Russian Program Assurance	0.0				0.0		+53.0	53.0
SPACE SHUTTLE	**3,059.0**		**-28.7**		**3,030.3**		**-32.0**	**2,998.3**
Shuttle Operations	2,487.4		-28.7		2,458.7		-32.0	2,426.7
Orbiter & Integration	573.4				573.4		+34.6	608.0
Propulsion	1,093.4		-28.7		1,064.7		-13.5	1,051.2
Mission & Launch Operations	820.6				820.6		-53.1	767.5
Safety & Performance Upgrades	571.6				571.6		0.0	571.6
Orbiter Improvements	234.8				234.8		0.0	234.8
Propulsion Upgrades	175.7				175.7		0.0	175.7
Flight Ops & Launch Site Equipment Upgrades					153.5		0.0	153.5
Construction of Facilities	7.6				7.6			7.6
PAYLOAD & UTILIZATION OPERATIONS	**182.0**				**182.0**		**-5.0**	**177.0**
Payload Processing & Support	39.2				39.2			39.2
Expendable Launch Vehicle Support	31.5				31.5			31.5
Advanced Projects	10.0				10.0			10.0
Engineering & Technical Base	101.3				101.3		-5.0	96.3

	FY 99 President's Budget	Gen'l Reductions	Approp. Adjust-Ments	Congress-ional Adds	FY99 Appropr. Budget	11/13/98 AXAF/Triana Changes	12/22/98 Changes	Initial FY99 Op Plan
SCIENCE, AERO & TECHNOLOGY	**4,938.4**	**-46.3**		**+242.8**	**5,653.9**	**0.0**	**0.0**	**5,653.9**
SPACE SCIENCE	**2,058.4**	**-21.2**		**+82.0**	**2,119.2**	**0.0**	**0.0**	**2,119.2**
AXAF Development					0.0	+39.0		39.0
SIRTF	111.7				111.7			111.7
Gravity Probe B mission	37.6				37.6		+5.0	42.6
TIMED	40.8				40.8		-3.0	37.8
Payload & Instrument Development	29.4				29.4		-0.5	28.9
Explorers	114.3				114.3			114.3
Mars Surveyor	164.0			+20.0	184.0		-4.3	179.7
Discovery	126.5				126.5	-16.1	-15.8	94.6
Mission Operations & Data Analysis	526.6	-21.2			505.4	-22.9	+8.2	490.7
Supporting Research & Technology	604.4			+62.0	666.4		+3.2	669.6
Suborbital	99.6				99.6		+1.7	101.3
Launch Services	203.5				203.5		+3.0	206.5
Construction of Facilities					0.0		+2.5	2.5
LIFE & MICROGRAVITY SCI & APPLICATIONS	**242.0**			**+21.5**	**263.5**		**0.0**	**263.5**
Advanced Human Support Technology Program	24.5				24.5			24.5
Biomedical Research & Countermeasures Program	50.0			+9.7	59.7			59.7
Gravitational Biology and Ecology Program	37.1			+3.8	40.9			40.9
Microgravity Research Program	106.7			+7.0	113.7			113.7
Space Product Development Program	14.4			+1.0	15.4			15.4
Occupational Health Research Function	0.7				0.7		+0.2	0.9
Space Medicine Research Function	6.9				6.9		-0.2	6.7
Mission Integration Function	1.7				1.7			1.7

	FY 99 President's Budget	Gen'l Reductions	Approp. Adjustments	Congressional Adds	FY99 Appropr. Budget	11/13/98 AXAF/Triana Changes	12/22/98 Changes	Initial FY99 Op Plan
EARTH SCIENCE	**1,372.0**	**-11.2**		**+53.0**	**1,413.8**	**0.0**	**0.0**	**1,413.8**
Earth Observing System	659.1			+13.4	672.5	-23.8	-17.6	631.1
EOS Data Information System	256.6			+11.6	268.2		-6.5	261.7
Earth Probes	85.9				85.9	+23.8		109.7
Applied Research & Data Analysis	365.4	-11.2		+28.0	382.2		+18.4	400.6
GLOBE	5.0				5.0			5.0
Launch Services	0.0				0.0		+4.2	4.2
CoF	0.0				0.0		+1.5	1.5
AERO & SPACE TRANSPORTATION TECH	**786.0**	**-13.9**		**+47.8**	**1,338.9**		**0.0**	**1,338.9**
Aeronautics	786.0	-13.9		+1.8	773.9		-5.0	768.9
Aeronautics Reserach & Technology Base	418.0			+1.8	419.8		+4.3	424.1
(Construction of Facilities)					--		(+2.5)	(+2.5)
Aeronautics Focused Programs	368.0	-13.9			354.1		-9.3	344.8
HPCC	20.6				20.6			20.6
High Speed Research	190.0				190.0		-9.3	180.7
Advanced Subsonic Technology	157.4	-13.9			143.5			143.5
Advanced Space Transportation	388.6			+36.0	424.6		+5.0	429.6
Commercial Technology	130.4			+10.0	140.4		0.0	140.4
MISSION COMMUNICATION SERVICES	**380.0**			**--**	**380.0**		**0.0**	**380.0**
Ground Network	228.9				228.9		-17.7	211.2
Mission Control & Data Systems	145.4				145.4		-2.3	143.1
Space Network Customer Services	27.3				27.3		-1.6	25.7
Management Challenge	-21.6				-21.6		+21.6	0.0
ACADEMIC PROGRAMS	**100.0**			**+38.5**	**138.5**			**138.5**

	FY 99 President's Budget	Gen'l Reductions	Approp. Adjustments	Congressional Adds	FY99 Appropr. Budget	11/13/98 AXAF/Triana Changes	12/22/98 Changes	Initial FY99 Op Plan
MISSION SUPPORT	**2,476.6**		**+31.0**	**+3.5**	**2,511.1**		**0.0**	**2,511.1**
SMAEAC	**35.6**				**35.6**			**35.6**
SPACE COMMUNICATION SERVICES	**177.0**		**+8.8**		**185.8**		**0.0**	**185.8**
Space Network	129.2				129.2		-18.9	110.3
Telecommunications	79.7		+8.8		88.5		-13.0	75.5
Management Challenge	-31.9				-31.9		+31.9	0.0
RESEARCH & PROGRAM MANAGEMENT	**2,099.0**		**+22.2**		**2,121.2**		**0.0**	**2,121.2**
Personnel & Related Cost	1,577.1		+20.8		1,597.9		+4.9	1602.8
Travel	47.4		+1.4		48.8			48.8
Research Operations Support	474.5				474.5		-4.9	469.6
CONSTRUCTION OF FACILITIES	**165.0**			**+3.5**	**168.5**			**168.5**
INSPECTOR GENERAL	**20.0**				**20.0**			**20.0**
TOTAL NASA	**12,946.0**	**-46.3**		**+246.3**	**13,146.0**	**--**	**--**	**13,146.0**